CANADIAN JOURNAL OF ANIMAL SCIENCE

(formerly published as part of *Canadian Journal of Agricultural Science*)

The official publication of the Canadian Society of Animal Production

VOLUME 37 JUNE, 1957 No. 1

SEASONAL AND REGIONAL VARIATIONS IN THE UNSATURATED ACIDS OF ALBERTA BUTTERFAT[1]

F. W. Wood[2] and W. Haab[3]

University of Alberta, Edmonton, Alberta

[Received for publication April 30, 1956]

ABSTRACT

Monthly samples of butterfat taken during 1953-54 from creameries at Edmonton and Lethbridge showed regional and seasonal fluctuations of iodine values and content of monoenoic and conjugated and non-conjugated dienoic, trienoic and tetraenoic acids. The total unsaturated acids content, as measured by iodine values, was higher in the Edmonton butterfats and reached a maximum in September at the end of the grazing season, while the lower Lethbridge maximum occurred in May with but slightly declining values throughout the summer. Minimum values were recorded during November and December for both regions. Maximum oleic acid occurrence did not coincide with the peak of the grazing season. Most of the polyunsaturated acids varied seasonally but marked regional differences were not observed. In general the latter constituents occurred in amounts comparable to those reported elsewhere. With the exception of the non-conjugated dienoic acids, summer values were high and winter values low. Conjugated tetraenoic acids were found in all butterfats but in trace amounts only.

INTRODUCTION

While there is much information on seasonal and regional variability of the total unsaturated acid content of butterfat, there is only a limited amount of information of this nature for the polyunsaturated acid components (5, 6, 9). Data for seasonal variations of the polyunsaturated acids of Canadian butterfat have only become available since this research project was undertaken[4] and they are limited to butterfat obtained from a small number of pure bred herds. Knowledge of these minor constituents is important in studies of the nutrient properties, the oxidative deterioration and the body and texture of butter. This is particularly true in the butter-producing regions of the Canadian prairies, where little, if any, supplemental concentrate or succulent roughage is fed during the winter season to herds producing churning cream. The data presented below will have broad implications in western Canadian butter problems.

[1]This study was supported as EMR Project No. 18 by Science Service, Department of Agriculture, Ottawa, Canada.

[2]Department of Dairying, University of Alberta, Edmonton, Alta.

[3]*Present address*—Department of Dairy Industry, University of California, Davis, Calif.

[4]Unpublished data, Department of Dairy Science, University of Manitoba, Winnipeg, Man.

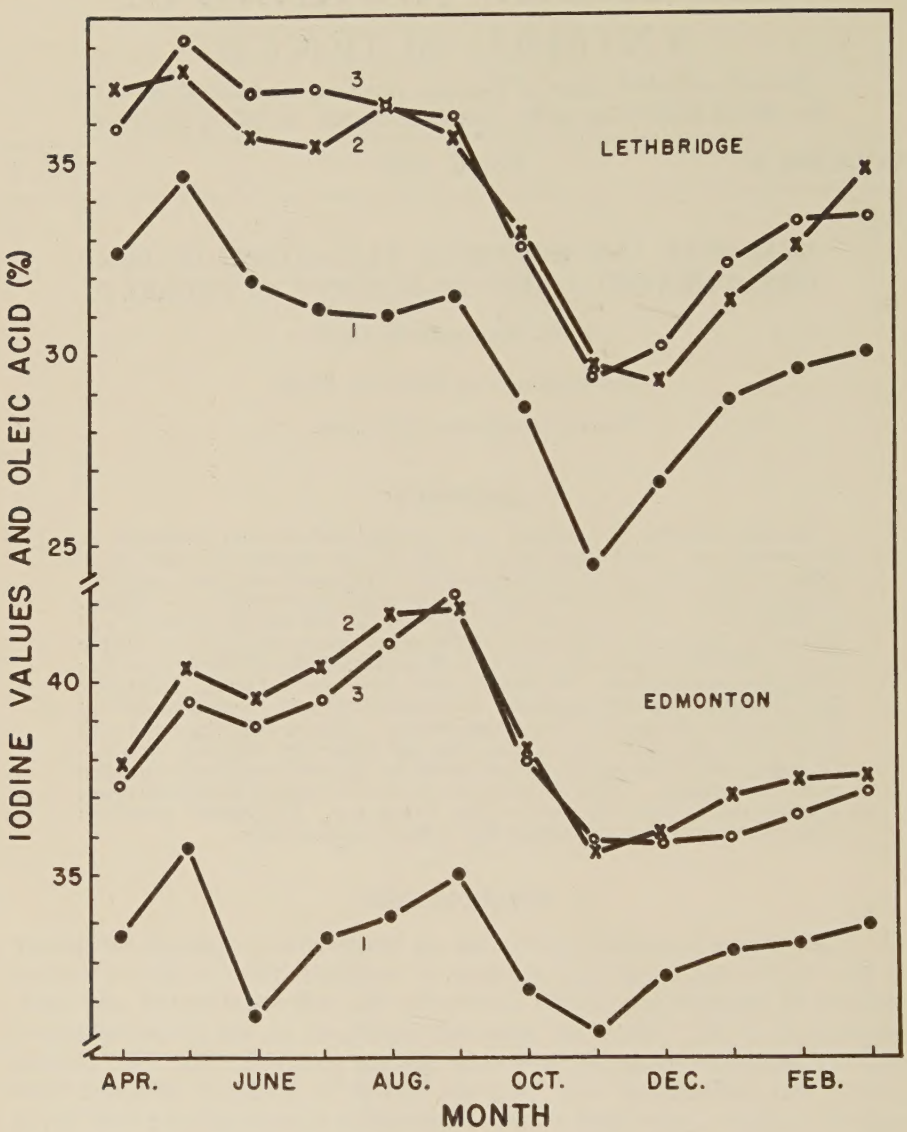

FIGURE 1. Seasonal and regional variations in iodine value and content of oleic acid. 1—oleic acid 1953-54; 2—iodine values 1952-53; 3—iodine values 1953-54.

METHODS

Butter was received weekly from creameries in the cities of Lethbridge and Edmonton, located in the southern and northern parts of the province of Alberta, respectively. Regional monthly composite samples of butter fats were prepared in the laboratory from these weekly butters. Iodine values were determined monthly over the 24-month period April 1952 to March 1954. The data for unsaturated acid content were obtained during the 12 months ending March 1954.

To prepare the composite samples, equal portions of the appropriate weekly butters were melted together at 60°C. and the decanted liquid butterfat was filtered through Whatman No. 1 filter paper in a 50°C. chamber. The clear, dry, filtered butterfat was then stored at −20°C. until analysed.

Iodine values were determined by the Wijs method (1). The conjugated and non-conjugated acids were estimated by the spectrophotometric method of Brice *et al.* (2, 3) which employs the KOH-glycerol-air technique with an isomerization time of 45 minutes. Iso-octane (spectro grade 2, 2, 4-trimethylpentane, Eastman) was the solvent in the determination of conjugated acids and methanol (absolute, reagent grade, Merck) in the determination of non-conjugated acids. Oleic acid was calculated by the A.O.C.S. method (1) and includes all the monoenoic acids of the butterfat. All acid determinations were in duplicate and are reported as average acid percentages in the butterfat.

RESULTS

Iodine values and oleic acid

The monthly iodine values and the oleic acid contents are compared regionally and seasonally in Figure 1 and the ranges for each region may be seen in Table 1.

There are some striking regional differences to be noted in the iodine values of the butterfats but the data for 1953-54 were not significantly different statistically from those for 1952-53 (10). The iodine values were higher in the northern than in the southern district. These values for the Edmonton butterfats reached their maxima during September, while Lethbridge butterfats exhibited highest values in May with a gradual decline to the minima (a slight August upturn is to be noticed in the 1952-53 curve). The minima occurred during November-December in all cases.

Although the seasonal trends of oleic acid in the two areas are in general somewhat similar, there are some seasonal and regional differences and peculiarities worthy of note. Northern butterfats were considerably

TABLE 1.—RANGES OF IODINE VALUES AND PERCENTAGE OCCURRENCE OF UNSATURATED ACIDS

Acid	Edmonton	Lethbridge
Oleic	31.2 —35.7	24.5 —34.7
Conjugated dienoic	0.63 — 1.80	0.5 — 1.33
" trienoic	0.014— 0.029	0.016— 0.031
" tetraenoic	0.002— 0.005	0.003— 0.004
Non-conjugated dienoic	1.23 — 1.67	1.22 — 1.66
" trienoic	0.54 — 1.31	0.51 — 1.04
" tetraenoic	0.27 — 0.49	0.27 — 0.42
Iodine value	35.8 —41.9	29.4 —38.2

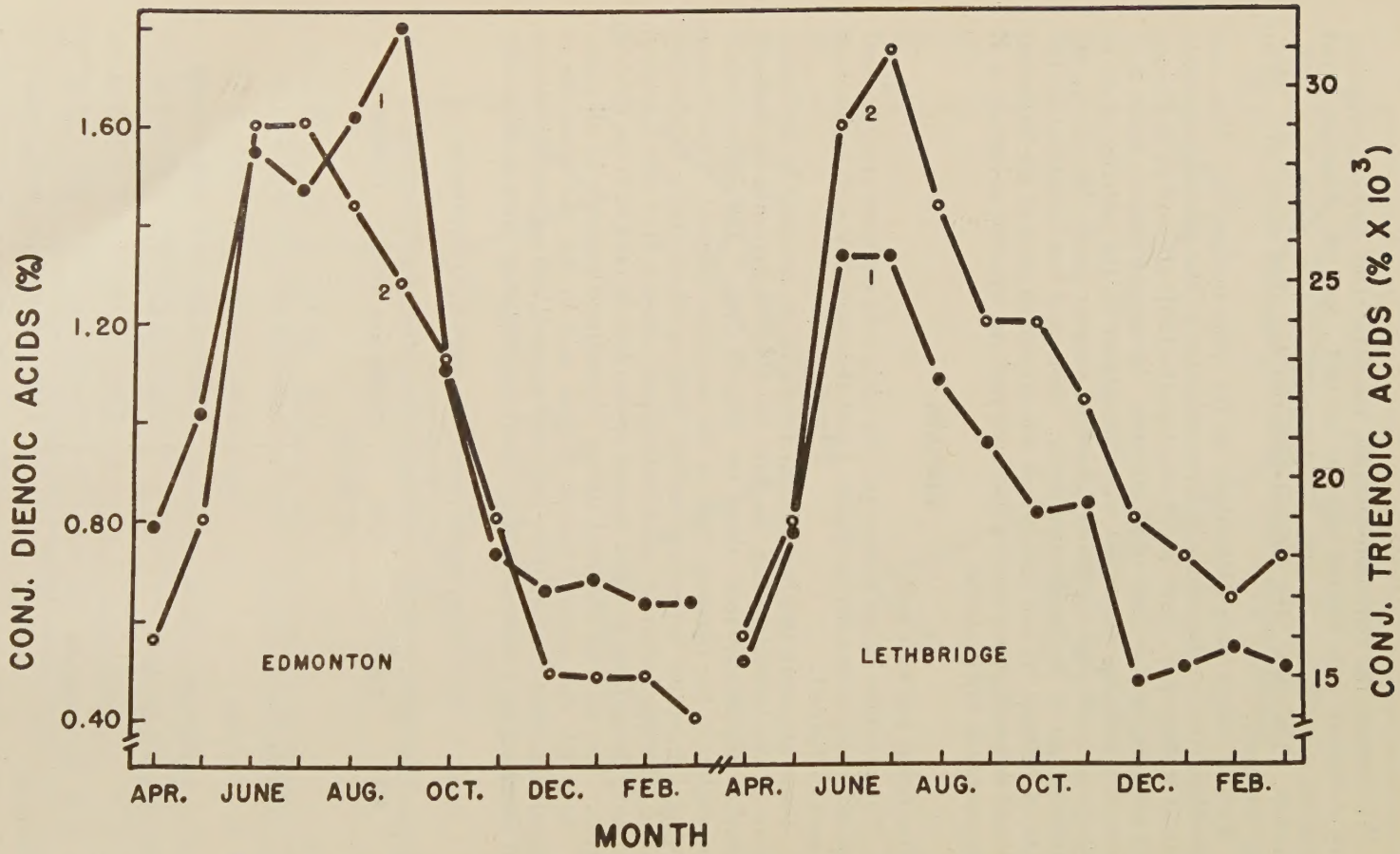

FIGURE 2. Seasonal and regional variations in the content of conjugated dienoic and trienoic acids.
1—dienoic acids; 2—trienoic acids.

higher but less variable in oleic acid content than were the southern butterfats. The maximum and minimum occurred in the months of May and November respectively in each region and the maximum was followed by lower values throughout the grass feeding months. The oleic acid content of the Edmonton butterfats increased from a low value in June, which was almost at the minimum, to a point in September slightly below the maximum. On the other hand, the Lethbridge oleic acid content decreased from the May maximum until August, when a slight upward deflection of the curve (Figure 1) is observed.

Conjugated polyunsaturated acids

Conjugated dienoic, trienoic and tetraenoic acids were found in all samples of butterfat examined (Table 1 and Figure 2).

The conjugated dienoic and trienoic acids of each region displayed definite seasonal trends with maximum values in the grazing season, May to September, and minimum values during the stall-feeding period. The Edmonton dienoic acid maximum occurred in September, coinciding with a point of high oleic content and maximum iodine value for this region. The rapid decrease from peak occurrence of dienoic and trienoic acids in Lethbridge butterfat was interrupted between September and November, when the feeding of beet-tops and other beet by-products is common practice in the irrigated sections of this area. Although only traces of tetraenoic acids were found, there may have been a seasonal trend in the Edmonton butterfats with the maximum in June and the minimum during the winter months.

Non-conjugated polyunsaturated acids

The data in Table 1 indicate that the non-conjugated polyunsaturated acids do not vary with the region in Alberta. Seasonal trends are shown graphically in Figure 3. The dienoic acids displayed no distinct seasonal trend in either region, although there was a peak during October and November in the Edmonton curve. It is quite apparent that the trienoic acid content was high in both regions during the pasture season with maximum values in July followed by a rapid decline to winter levels. The Lethbridge curve exhibits a temporary rise in November which is similar to the behaviour of that for the conjugated dienoic and trienoic acids of this region. The Edmonton non-conjugated trienoic acids were at the maximum level from July to September and thereafter declined precipitously to winter levels by December. In the same region the non-conjugated tetraenoic acids appeared to display seasonal variation with a maximum in June followed by gradual decline.

DISCUSSION

Edmonton is approximately 250 miles north of Lethbridge which is situated in the irrigation area of southern Alberta. Butterfats from these regions should show the effects of the extremes in climate and feeding conditions for the butter-producing regions of this province.

Since iodine values are sensitive to the presence of all unsaturated acids, of which oleic acid makes up the bulk, a close parallelism between the oleic acid and iodine value curves was to be expected. Some small deviations from parallel trends may be accounted for by the seasonal variation of the polyunsaturated acids. That oleic acid did not reach its

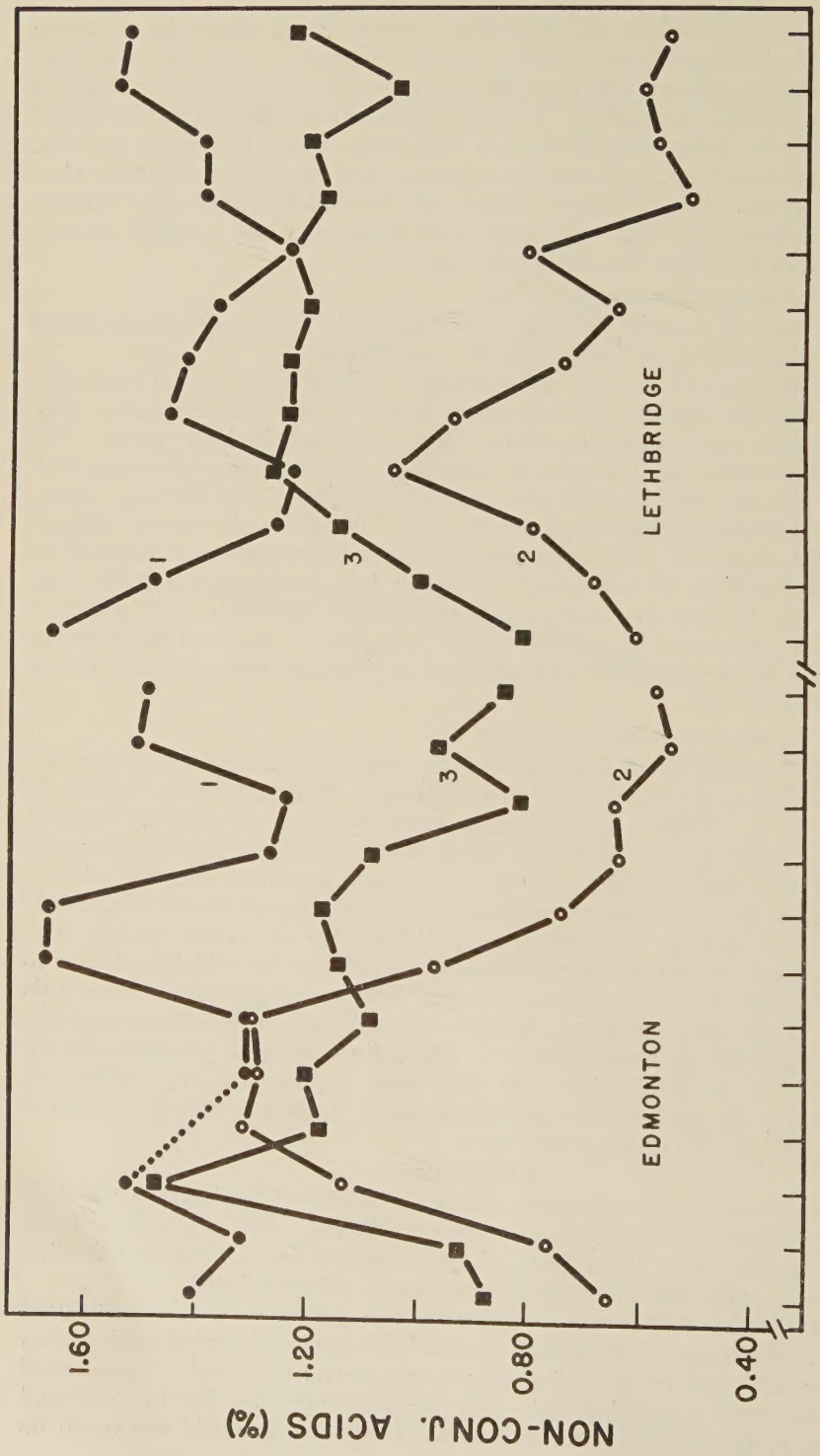

FIGURE 3. Seasonal and regional variations in the content of non-conjugated dienoic, trienoic and tetraenoic acids. 1—dienoic acids; 2—trienoic acids; 3—tetranoic acids (1% x 3).

maximum in September in Edmonton butterfats, when the iodine values were at the seasonal maximum in two successive years, suggests the involvement of unsaturated acids other than oleic.

The pattern of seasonal fluctuations of oleic acid and iodine values in both regions, but especially in the Lethbridge area, differed from that reported in New Zealand (4, 6) in that the Alberta oleic acid content was not at the minimum level at the peak of the pasture season, and differed from English conditions in that the maximum Alberta iodine values did not occur during the lush grass season. The maximum iodine value in the Edmonton region occurred in September. This is similar to Swedish (7) and Dutch (9) findings.

The conjugated dienoic and trienoic acids in Alberta and Dutch butterfats have similar seasonal trends, although in the latter country near-maximum values are maintained from May to October for dienoic acid and from May to September for trienoic acid. The conjugated polyunsaturated acids of Alberta butterfats were found in quantities comparable to those reported in California by Smith and Jack (8) and in New Zealand and other countries as summarized by McDowell (6), except that New Zealand butterfats were reported to be devoid of conjugated tetraenoic acids.

The non-conjugated dienoic acid content is of the same general quantitative level as that reported in Sweden (5), the Netherlands and California but considerably higher than in New Zealand. The lack of a seasonal trend is similar to the behaviour of this component in Swedish butterfat and dissimilar to its behaviour in the Netherlands where high winter and low summer values were reported.

Reference has been made to the influence of the type of feed on the seasonal and regional variations in these butterfat constituents. Undoubtedly, other factors, such as plane of nutrition, lactation period and ambient temperature, which are believed to incite variability, also contributed to the variations found.

REFERENCES

1. American Oil Chemists' Society. Official and tentative methods. Chicago, Ill. 1952.
2. Brice, B. A., Margaret L. Swain, B. B. Schaeffer, and W. C. Ault Spectrophotometric determination of small proportions of polyunsaturated constituents in fatty materials. Oil and Soap 22 : 219-224. 1955.
3. Brice, B. A., Margaret L. Swain, S. F. Herb, P. L. Nichols, and R. W. Riemenschneider. Standardization of spectrophotometric methods for determination of polyunsaturated fatty acids using pure natural acids. J. Amer. Oil Chemists' Soc. 29 : 279-287. 1952.
4. Hansen, R. P., and F. B. Shorland. Seasonal variations in fatty acid composition of New Zealand butterfat. Biochem. J. 52 : 207-216. 1952.
5. Mattsson, S. Polyunsaturated fatty acids in butter and their influence on the oxidation of butter. Methods of analysis and preliminary results. 12th Intern. Dairy Congr. Proc., Stockholm, 2 : 308-323. 1949.
6. McDowell, A. K. R. The properties of New Zealand butters and butterfats. III. Seasonal variations in the nature of the unsaturated acids of butterfat as estimated by spectrophotometric methods. J. Dairy Research 20 : 101-107. 1953.
7. Platon, B., and T. Olsson. Undersökningar över jodal och brystningstal has mjölkōch smörfett. Meddelande Statens Mejeriförsök Nr. 8. 1941.
8. Smith, L. M., and E. L. Jack. The unsaturated fatty acids of milk fat. II. Conjugated and non-conjugated constituents. J. Dairy Sci. 37 : 390-398. 1954.
9. Stadhouders, J., and H. Mulder. The composition of Dutch butterfat. I. Seasonal variations in the unsaturated fatty acid composition of butterfat. Netherlands Milk and Dairy J. 9 : 182-193. 1955.
10. Wood, F. W. Seasonal and regional variations in some chemical and physical properties of Alberta butterfat. Can. J. Agr. Sci. 36 : 422-429. 1956.

EVALUATION OF METHODS OF ESTIMATING POPULATIONS OF THE SHEEP KED, *MELOPHAGUS OVINUS* (L.) (DIPTERA: HIPPOBOSCIDAE), ON MATURE EWES AND YOUNG LAMBS[1]

W. A. NELSON[2], S. B. SLEN[3] AND E. C. BANKY[3]

Canada Department of Agriculture, Lethbridge, Alberta

[Received for publication November 27, 1956]

ABSTRACT

Six methods of estimating populations of the sheep ked, *Melophagus ovinus* (L.), on mature ewes and young lambs of four breeds were evaluated. The actual populations were determined by picking off and counting all the keds. The total live count method gave the highest degree of accuracy, the ratios of the sample counts to the actual populations not being affected by variations in the degree of infestation, body size, or fleece characteristics. A valid estimate was obtained by counting all the keds on only one side of the sheep. In the vertical parting methods the ratios increased as the distance between the partings decreased, and counts were affected by marked differences in body size and fleece characteristics. The 12-inch parting method accounted for only a small portion of the ked population and the accuracy was low. In the 5-minute count the ratio depended on the degree of infestation, body size, and to a lesser degree the fleece characteristics.

INTRODUCTION

In chemical control and population studies of the sheep ked, *Melophagus ovinus* (L.), with relatively large numbers of animals, accurate estimates of numbers are necessary. However, the uneven distribution of the ked population over the body of the sheep [Bosman *et al.* (1), and Evans (4)] and the wide variations in body size and fleece characteristics of the host make it difficult to estimate populations. MacLeod (7) indicated that the "total live count", i.e., carefully counting all keds seen on the body, closely approximated the number of keds present on the animal. Bosman *et al.* (1), Denning (3), Matthysse (8), and Pfadt *et al.* (11) also used this method of estimating ked populations. Fairchild *et al.* (5) observed that more keds were found on the neck than on any other body region. Consequently, they counted all keds found on one side of the neck, including the area from the base of the shoulder to the base of the ear, to obtain an estimate of the population. Hoffman *et al.* (6) estimated the total population by counting all the keds on one side of the animal and multiplying this figure by two. Estimates were not correlated with actual numbers in any of these methods. Muma *et al.* (9) counted all keds exposed in ten evenly spaced 12-inch-long vertical partings on each side of the animal, the partings being distributed from head to tail. They obtained a correlation coefficient of + 0.89 between the estimated and actual populations, and concluded that this method gave a valid estimate. In a recent note by Nelson and Slen (10), four methods of estimating ked populations on feeder lambs were evaluated. This paper reports the results of testing these and other methods on mature ewes and young lambs.

[1] Joint Contribution from the Entomology Division (No. 3320), Science Service, and the Animal Husbandry Division, Experimental Farms Service, Department of Agriculture, Ottawa, Canada.

[2] Associate Entomologist, Veterinary and Medical Entomology Section, Science Service Laboratory, Lethbridge, Alta.

[3] Experimental Farm, Lethbridge, Alta.

PROCEDURE

Materials

Suffolk, Cheviot, Canadian Corriedale, and Rambouillet ewes were used. The lambs were of the same breeds, except that Rambouillet x Suffolk crossbreds were used instead of Rambouillets. Each ewe was infested artificially with 200 keds in October, 1952, about six months before counting. The lambs were infested by natural transfer from the ewes. The lambs were approximately ten weeks of age when the counts were made.

Methods of Counting

All counts were completed on one animal before proceeding to the next. These were made on the ewes from February to May, 1953, and on the lambs during May and June, 1953. The following six methods were tested: (a) the total live count of MacLeod (7), the number for each side of the sheep being recorded separately for comparison with the picked-off counts from the entire sheep; (b) the 5-minute count (10); (c) the 12-inch parting method (9); (d – f) the vertical parting method (10), with partings made at 2-, 3-, and 4-inch intervals, beginning at the anterior point of the shoulder. The actual population was determined by picking off and counting all keds found on each animal.

Statistical Analysis

The main criterion of a satisfactory method of estimation is that the ratio of the sample count to the actual population be unbiased, i.e., unaffected by the person counting, degree of infestation, body size, or breed or fleece characteristics. A detailed analysis of these ratios was therefore made under the following assumptions:—

1. The regression lines passed essentially through the origins. This was checked by plotting the sample counts against the total picked-off counts for each method separately. All the data were linear, with the exception of the 5-minute count, which showed a slight curvilinearity. By correlation analysis, again, only in the 5-minute count was there a significant ($p < .01$) relationship between ratios and totals for both ewes and lambs.

2. The standard deviations of the counts were proportional to the sizes of the counts. It was found that the variation of the counts increased as the degree of infestation increased. This is illustrated in the scatter diagram for the total live count (Figure 1), which shows a gradual spreading of the counts away from the origin. The validity of this assumption is, however, somewhat restricted by the theoretical relationship between the size of the population and relative error of the estimate [(Burns (2)]

$$\text{P.E.} = \sqrt{\frac{(1 - p)}{np}},$$

where P.E. = percentage error; n = total counted; p = percentage of the total counted. According to the above equation, the percentage error inherent in the estimates would be inversely affected by sample

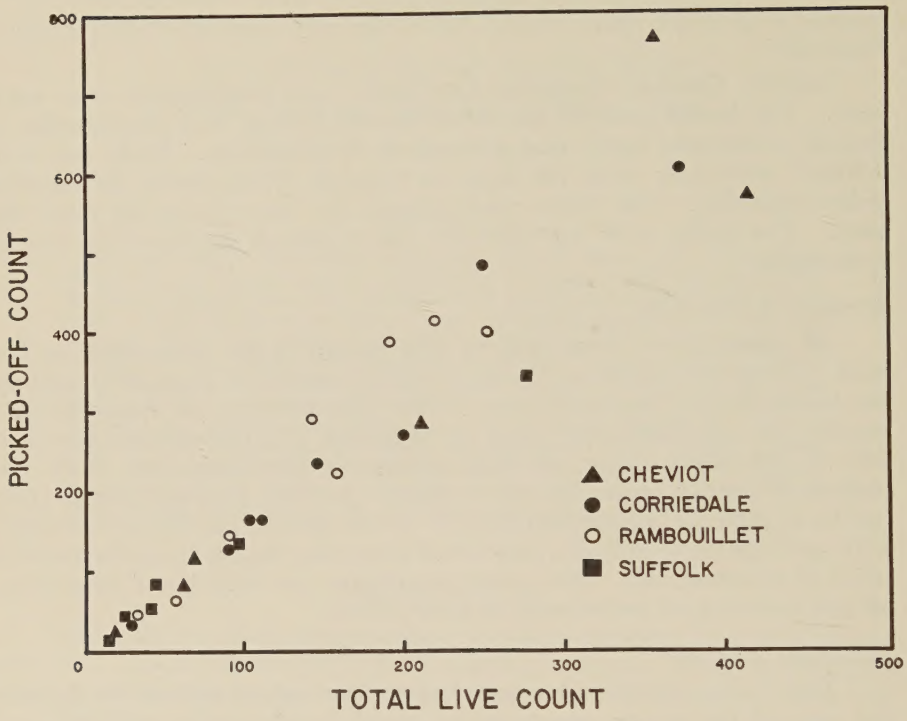

FIGURE 1. Relationship of the counts obtained by counting all the keds seen on both sides of the body (total live count) to the picked-off counts for the various breeds.

size. This effect, however, is small, if there are not great variations in the size of the populations. For this reason it was neglected.

To assess the reliability of the various methods, the ratios were transformed into logarithms and their respective standard deviations calculated. Since a relative, rather than an absolute, measure of the variability was needed, the standard deviations were converted into coefficients of variation.

Whenever the ratios were subjected to analysis of variance they were first converted into logarithms.

RESULTS AND DISCUSSION

Table 1 shows by age groups and breeds the average numbers of keds counted by the six methods, the total picked-off counts, and the ratios of the sample counts to the total picked-off counts.

Table 2 shows that the coefficients of variation of the ratios varied least in the total-live count method for both lambs and ewes. This was followed by the vertical parting methods, where the variation tended to increase as the distance between partings increased, the 12-inch vertical parting method ranking between the 3-inch and the 4-inch vertical parting methods. The relatively high variation in the 5-minute count occurred partly because sample size affected the ratio. Tables 1 and 2 indicate that the methods giving the highest ratios had the lowest coefficients of variation.

TABLE 1.—AVERAGE NUMBERS OF KEDS COUNTED AND AVERAGE RATIOS OF THE SAMPLE COUNTS TO THE TOTAL PICKED-OFF COUNTS FOR VARIOUS METHODS OF ESTIMATING POPULATIONS OF THE SHEEP KED ON LAMBS AND EWES OF VARIOUS BREEDS

Method	LAMBS										EWES									
	Suffolk		Cheviot		Canadian Corriedale		Ramb. x Suff.		Average		Suffolk		Cheviot		Canadian Corriedale		Rambouillet		Average	
	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio
Number of animals	9		10		7		11				6		7		8		8			
Picked-off count	98.4	1.000	241.9	1.000	335.3	1.000	102.2	1.000	183.1	1.000	111.7	1.000	457.7	1.000	259.9	1.000	246.0	1.000	273.1	1.000
5-minute count	37.7	.396§	98.6	.449‡	122.7	.386‡	57.4	.692†	76.1	.481	32.2	.274§	58.7	.197‡	49.8	.200‡	41.0	.173	45.9	.211
2-in. vertical partings	26.0	.238‡	57.5	.253	73.1	.232	27.4	.294	43.1	.254	37.5	.365†‡	120.7	.309*	65.1	.262	55.0	.229	70.0	.291
3-in. vertical partings	17.4	.184	40.3	.177	56.7	.179	21.9	.248*	32.4	.197	26.3	.220	103.1	.186	47.4	.181	39.5	.175	54.3	.190
4-in. vertical partings	12.6	.136§	31.8	.136	44.6	.145	18.2	.203	25.5	.155	20.0	.190§	83.1	.175	38.4	.157	29.9	.135	43.0	.164
Total live count	68.7	.710	184.5	.780	241.1	.734	75.2	.814	134.5	.760	72.3	.729	301.8	.675	160.6	.650	140.9	.610	171.0	.666
Ten 12-in. vertical partings			—		not applicable		—				13.0	.141	52.6	.104	34.9	.130	27.6	.113	33.1	.122

†Significantly greater than those for remaining breeds ($P < .01$).
*Significantly greater than those for remaining breeds ($P < .05$).
‡Significant differences between lambs and ewes ($P < .01$).
§Significant differences between lambs and ewes ($P < .05$).

TABLE 2.—COEFFICIENTS OF VARIATION OF THE RATIOS OF THE SAMPLE COUNTS (x) TO THE TOTAL PICKED-OFF COUNTS (y) FOR VARIOUS METHODS OF ESTIMATING POPULATIONS OF THE SHEEP KED ON LAMBS AND EWES OF VARIOUS BREEDS

Method	LAMBS					EWES				
	Suffolk	Cheviot	Canadian Corriedale	Ramb. x Suffolk	Average	Suffolk	Cheviot	Canadian Corriedale	Rambouillet	Average
5-minute count	27.6	22.8	34.1	39.1	31.3	31.6	61.2	31.6	19.1	37.7
2-in. vertical partings	20.9	18.5	38.2	39.6	30.3	34.1	26.1	22.0	24.6	27.0
3-in. vertical partings	35.7	22.8	33.5	32.3	31.3	35.9	91.2	32.1	31.2	50.3
4-in. vertical partings	45.7	22.8	47.4	66.9	47.2	23.5	35.3	26.1	34.2	30.0
Total live count	15.8	13.6	14.1	21.9	16.6	27.0	20.1	13.2	20.9	20.1
Ten 12-in. vertical partings	—	—	not applicable	—	—	17.3	30.9	36.9	60.1	38.1

In the total live count, analysis of variance showed no significant difference between the ratios for the two sides of the same sheep in any of the breed or age groups. Therefore, a valid estimate may be obtained by counting the keds on one side of the body only.

In the 5-minute count the number of keds counted in a 5-minute interval is used to make the estimate. Theoretically, this is a valid estimate provided that the surface area is specified and the time factor of the operation is negligible. However, in practice a considerable portion of the time available is spent in performing the counts, parting the fleece, locating the keds, and so on. For this reason, and because of individual differences in the body surface area, the ratio may be expected to depend not only on the operator but also on the degree of infestation, fleece characteristics, and body size. This was demonstrated partly by the data presented in this paper. Consequently the time-constant method was considered inadequate for estimating ked populations.

The 12-inch vertical parting method of Muma *et al.* (9) accounted for only a small portion of the ked population. It is mainly for this reason that the accuracy of the method, as reflected in the coefficients of variation of the ratios, was relatively low. Also, the estimates became increasingly unreliable as the numbers of keds approached 10, and below this the estimates were obviously erroneous. It has been observed by Bosman *et al.* (1) and MacLeod (7) that the distribution of the keds over the body is not random and that the preferential locations depend to a considerable degree on the environment. Therefore the estimates are probably biased due to body size, because the 12-inch partings sample different degrees of infestation on lambs as compared to ewes. However, this was not investigated in the present study.

The vertical parting methods were designed to overcome the limitations of the 12-inch parting method by extending the partings from the mid-back to the mid-belly and covering the entire sheep. As would be expected, the ratios decreased as the distance between partings increased. In addition, the methods were subject to a bias resulting from differences in body size and fleece characteristics.

The total live count was the only satisfactory method of those studied. A relatively large portion of the actual population was counted and the coefficients of variation of the ratios were lower than those of the other methods, indicating a relatively high degree of accuracy. No significant differences between breeds and age groups were evident. This would permit a direct comparison of the total live counts in sheep populations where pronounced breed and size differences existed.

ACKNOWLEDGEMENTS

Thanks are due to M. Qually, Veterinary and Medical Entomology Section, Science Service, Lethbridge, Alta., for his assistance with the ked counts.

REFERENCES

1. Bosman, S. W., M. L. Botha, and D. J. Louw. Effect of the ked on Merino sheep. South Africa Dept. Agr. Sci. Bull. 281. 1950.
2. Burns, M. Observations on Merino x Herdwick hybrid sheep with special reference to the fleece. J. Agr. Sci. 46 : 389-406. 1955.
3. Denning, D. G. Dusting for sheep tick control. J. Econ. Entomol. 42 : 582-583. 1949.
4. Evans, G. O. Studies on the bionomics of the sheep ked, *Melophagus ovinus* L. in West Wales. Bull. Entomol. Research 40 : 459-478. 1950.
5. Fairchild, H. E., R. A. Hoffman, A. W. Lindquist, and D. C. Mote. A comparison of the chlorinated hydrocarbon insecticides for control of the sheep tick. J. Econ. Entomol. 42 : 410-414. 1949.
6. Hoffman, R. A., A. R. Roth, and A. W. Lindquist. Effect of air temperature on the insecticidal action of some compounds on the sheep tick and on migration of sheep tick on the animal. J. Econ. Entomol. 42 : 893-896. 1949.
7. MacLeod, J. The distribution and dynamics of ked populations, *Melophagus ovinus* Linn. Parasitology 39 : 61-68. 1948.
8. Matthysse, J. G. Large scale power dusting of feeder lambs for winter control of the sheep tick. J. Econ. Entomol. 38 : 285-290. 1945.
9. Muma, M. H., R. E. Hill, E. Hixson, and L. Harris. Control of sheep ticks on feeder lambs. J. Econ. Entomol. 45 : 833-838. 1952.
10. Nelson, W. A., and S. B. Slen. Note on evaluating populations of the sheep ked, *Melophagus ovinus* (L.) (Diptera: Hippoboscidae), on feeder lambs. Can. J. Agr. Sci. 33 : 620-621. 1953.
11. Pfadt, R. E., L. H. Paules, and G. R. DeFoliart. Effect of the sheep ked on weight gains of feeder lambs. J. Econ. Entomol. 46 : 95-99. 1953.

INTRA-TESTICULAR TEMPERATURE AND FERTILITY OF BISON, CATTALO, AND HEREFORD YEARLING BULLS

H. F. Peters[1] and K. B. Newbound[2]

[Received for publication March 26, 1956]

ABSTRACT

Intra-testicular temperatures of seven bison (Bison Americanus), eleven Hereford (Bos taurus), and eleven Cattalo (1/8- to 3/8-bison), yearling bulls were measured by means of a thermocouple technique. The mean temperatures were 93.9 ± 4.0° F, 91.0 ± 3.7° F, and 86.8 ± 5.5° F for bison, Herefords, and Cattalo, respectively.

Weight of one testis (sans epididymis) was recorded for each of the fertility-tested bulls. Mean testis weights were 53.3 ± 6.8 grams for the bison, 201.3 ± 12.9 grams for the Herefords, and 89.9 ± 26.2 grams for the Cattalo. Breed differences in testis weight were significant at the 1 per cent level of probability. The Cattalo and Herefords did not differ significantly in body weight or age. However, the bison bulls weighed significantly less than the Cattalo and Herefords.

Fertility estimates were obtained on four bison, four Herefords, and the eleven Cattalo by removal of a testicle from each and microscopic examination of semen taken by smear from the tail of the epididymis. No spermatozoa were present in the bison samples; all of the Herefords and one of the Cattalo had good sperm concentration; three other Cattalo bulls appeared to have a low degree of fertility, as indicated by the presence of a few spermatozoa, and no spermatozoa were present in seven Cattalo samples.

The results of this study indicated that the yearling bison bulls may have been sexually immature.

INTRODUCTION

In hybridization experiments with domestic beef cattle and American bison, sterility of the male hybrids has prevented the development of a breed of Cattalo. No fertile first-cross bulls were obtained, according to Deakin, Muir and Smith (3). Semen from bulls of 1/8- to 1/4-bison breeding varies in quality from complete absence of spermatozoa to normal concentration and a small proportion of the bulls show varying degrees of fertility. Kristjansson[3] made cytological examination of testes from infertile Cattalo bulls in 1951. He found that primary spermatocytes were formed and then appeared to undergo progressive pycnosis. Apparently no reduction division occurred.

Deakin *et al.* (3) reported that the testes of bison appeared to be smaller than those of domestic cattle, and were kept up close to the body cavity in a scrotum that was characterized by a thick skin and a protective covering of hair. These authors suggested that spermatogenesis in the bison may take place at higher temperatures than in domestic cattle as an adaptation against severe winter conditions that would cause injury to testes in a pendulous, unprotected scrotum of the domestic type. The bison scrotal condition appeared to be partially dominant in the first-cross hybrids, while the one-fourth bison Cattalo showed some variation of

[1] Superintendent, Range Experimental Farm, Canada Department of Agriculture, Manyberries, Alberta.
[2] Professor of Physics, University of Alberta, Edmonton, Alberta.
[3] Kristjansson, F., Central Experimental Farm, Ottawa, Canada. *Personal correspondence.*

this characteristic. It was suggested that the hybrid germinal epithelium failed to develop normally owing to the testes being kept at a higher temperature caused by a thick scrotal skin and proximity to the body. This hypothesis was supported by the cryptorchid-like appearance of the seminiferous tubules of the $\frac{1}{2}$- and $\frac{1}{4}$-bison hybrids (3).

Genetic studies of the fruit fly (Drosophila species) have demonstrated that sterility of species hybrids in that genus can be ascribed to the interaction of genes on particular chromosomes. Dobzhansky (4) showed that the sterility in the hybrids between Drosophila pseudoobscura and D. persimilis was due to modification in the process of spermatogenesis, by which spermatids degenerate without being transformed into spermatozoa. The smaller the testes, the greater is the disturbance. Secondary sexual characteristics are normal. Backcross males with the X chromosome and autosomes of the same species have large testes and are usually fertile. The more dissimilar the X and autosomes are in species origin, the smaller the testes. Dobzhansky concluded that the X, second, third and fourth chromosomes each carry at least two genes concerned with sterility of the hybrids.

Genic sterility of a comparable nature is undoubtedly involved in some of the hybrid mammals—such a case has been observed by Moree (8) in deer mice (Peromyscus species). Just how the genes bring about the fact of sterility concerns complex physiological interactions.

A study of endocrine relations in Cattalo could, perhaps, throw some light on the nature of the factors contributing to male sterility. In a review on hypophyseal regulation of testicular functions, Turner (9) observed that follicle-stimulating hormone (FSH) and luteinizing hormone (LH) both produce testicular enlargement when administered separately to normal and hypophysectomized rats. The FSH increases the diameter of the seminiferous tubules, but it appears that spermatogenesis can be furthered much more effectively if FSH is combined with LH. Cupps, Laben and Mead (1) were able to increase the concentration of spermatozoa in bulls of low fertility by the injection of gonadotrophin that was high in FSH. In a later report (2), they described a syndrome in bulls in which abnormalities in the pituitary and adrenal glands were accompanied by low concentration of spermatozoa, abnormal spermatozoa and normal interstitial tissue. Libido was normal.

In order to obtain more information on the causes underlying infertility of male Cattalo, an experiment to determine intra-testicular temperature, testis weight, and fertility of bison, Hereford, and Cattalo, yearling bulls was undertaken at the Range Experimental Farm, Manyberries, Alberta, in July, 1953.

MATERIALS AND METHODS

To measure intra-testicular temperatures, a thermocouple was used, consisting of a 6-ft. length of varnished constantan wire (B. and S. Gauge # 30), jointed to two 20-ft. lengths of #18 copper with cotton insulation. The junctions were silver-soldered, ensuring stability. The other ends of the copper leads passed through the terminals of a knife switch with copper components and thence to the terminals of a portable Leeds and

Northrup galvanometer. The internal resistance of the galvanometer was 23 ohms and the current sensitivity was 0.85 microamperes per scale division. The knife switch was closed, shorting the galvanometer, thus protecting it against excess current when the temperature difference between the constantan-copper junctions exceeded 25° F. The thermocouple was calibrated, employing mercury thermometers and water baths. One water bath was kept at approximately 104° F., and the second between 80° F. and 90° F., in order to duplicate, as closely as possible, the temperatures to be encountered during the investigation. The calibration constant was 0.55 divisions per degree F. This value was checked on completion of the investigation and no significant change was observed.

Each bull was held in a squeeze chute in a standing position for the temperature study. The right leg (the one nearest the operator) was drawn forward with a draw-rope to prevent the animal from kicking. The reference junction of the thermocouple was inserted into the rectum of the animal under test, along with a clinical thermometer, to a distance of four inches. The clinical thermometer was compared with a calibrated laboratory thermometer at the conclusion of the experiments, the observed error being less than 0.1° F. The second junction of the thermocouple was positioned in the middle of one testicle (anteroposteriorly), using a heavy needle and a short length of cotton thread. The needle was pushed completely through the testicle drawing the free ends of the thread, which was tied to the soldered portion of the thermocouple junction.

Following the insertion of the thermocouple junctions, it was found that after two minutes equilibrium was reached, judged by the attainment of a steady galvanometer reading. During the subsequent two to three minutes no change in galvanometer reading was observed, providing the animal did not struggle violently. The reading of the clinical thermometer provided the body temperature, and at the same time the testicular temperature was calculated from the galvanometer reading, using the calibration constant of 0.55° F. per division and the temperature of the reference junction.

In this study, seven bison, eleven Cattalo and eleven Hereford, yearling bulls were used. Following the temperature measurements, semen tests were made on four of the bison, four of the Herefords, and the eleven Cattalo. One testicle from each animal (the one not pierced in the temperature test) was removed and a semen smear was taken from the tail of the epididymis for microscopic examination. Each testis (sans epididymis) was weighed in grams. Body weights of all animals were taken three days prior to the time of the thermocouple study.

The bison bulls were obtained from Elk Island Park, Lamont, Alberta, in December, 1952. The Hereford and Cattalo bulls were born and raised at the Manyberries Range Experimental Farm. All the animals were fed a finishing ration in the feedlot from December, 1952 until July, 1953. Although exact dates of birth of the bison were not available, Love* reported that the calving season at Elk Island Park extends from approximately April 15 to the end of June. The Herefords were born in May, 1952, and the Cattalo were born from April 18 to June 10, 1952. Average ages at

*Love, B., I. Superintendent, Elk Island Park, Lamont, Alberta. *Personal correspondence.*

the time of the thermocouple study were 439 days for the Herefords and 444 days for the Cattalo. The four Herefords for which testis weights were recorded averaged 434 days of age.

Five of the Cattalo bulls were out of first-cross hybrid cows and sired by Hereford bulls; two were out of hybrid cows and sired by Cattalo bulls; and four were out of $\frac{1}{4}$-bison Cattalo cows and sired by Cattalo bulls.

EXPERIMENTAL RESULTS

Table 1 gives the mean rectal and intra-testicular temperatures and the mean difference between them for each breed. Intra-testicular temperatures of Herefords did not differ significantly from those of bison or Cattalo although the difference between Cattalo and Herefords approached significance at the 5 per cent probability level. The values ranged from 87.1° F. to 101.5° F. for bison, 82.0° F. to 94.9° F. for Herefords, and 75.1° F. to 93.8° F. for Cattalo.

Fertility estimates, mean testis weights, and mean body weights are summarized in Table 2. The four Hereford bulls had good concentrations of spermatozoa and were rated as "fertile". No sperm cells were seen in any of the semen samples from the four bison bulls tested. One of the Cattalo bulls had a good concentration of spermatozoa and three

TABLE 1.—MEAN RECTAL AND INTRA-TESTICULAR TEMPERATURES OF BISON, CATTALO, AND HEREFORD YEARLING BULLS, JULY, 1953

Breed	No. of animals	Rectal temperature (° F.)		Intra-testicular temperature (° F.)		Mean diff. between rectal and intra-testicular temperatures (° F.)
		Mean	Standard deviation	Mean	Standard deviation	
Bison	7	105.0	1.1	93.9	4.0	11.1
Cattalo	11	103.9	1.0	86.8	5.5	17.2
Hereford	11	103.4	0.6	91.0	3.7	12.4

TABLE 2.—FERTILITY RATING, MEAN TESTIS WEIGHTS, AND MEAN BODY WEIGHTS OF BISON CATTALO, AND HEREFORD YEARLING BULLS TESTED IN 1953

Breed	No. of animals			Testis weight[1] (grams)		Body weight[3] (pounds)	
	Fertile	Low degree of fertility	Sterile	Mean	Standard deviation	Mean	Standard deviation
Bison	0	0	4	53.3	6.8	596.2[2]	7.4
Cattalo	1	3	7	89.9	26.2	776.4	80.8
Hereford	4	0	0	201.3	12.9	770.0	12.8

[1] Breed differences significant ($P = 0.01$).

[2] Significantly less than other breeds ($P = 0.01$).

[3] Includes only the four bison and four Herefords for which testis weights were recorded. Average weights of entire lots were 584.3 ± 16.4 lb. for bison and 772.7 ± 37.7 lb. for Herefords.

others appeared to have a low degree of fertility, as indicated by the presence of a few spermatozoa. No spermatozoa were seen in the other Cattalo samples.

The one Cattalo bull that appeared to be fertile had a testicular temperature of 92.5° F. and a testis weight of 117.2 grams. His body weight was 715 lb. This bull was out of a hybrid cow and was sired by a Hereford bull. The three Cattalo bulls that appeared to have a low degree of fertility had testicular temperatures of 83.1° F., 83.1° F., and 93.8° F., respectively. Their testis weights were 97.5, 144.1, and 97.0 grams, respectively. The seven sterile Cattalo bulls had a range in testicular temperatures from 75.1° F. to 93.1° F., with an average of 86.0° F. They had a range in testis weight from 40.0 grams to 102.1 grams, with an average of 76.2 grams.

The breed differences in testis weight were statistically significant ($P = 0.01$).

The Cattalo bulls did not differ significantly from the Herefords in age or body weight. A simple correlation study within the Cattalo group showed a low, non-significant correlation ($r = 0.226$) between body weight and testis weight. The lowest testis weight (40.0 grams) was that of a sterile Cattalo bull which weighed 865 lb., the second highest body weight recorded in this study. The Cattalo bull which appeared to have a low degree of fertility and had a testis weight of 144.1 grams was the heaviest animal, with a body weight of 960 lb.

DISCUSSION

The infertility and low testis weights of the yearling bison bulls indicates that male bison may reach puberty later than domestic cattle. The comparatively low testis weights of the bison may have been due in part to their lower body weight; however, it is not likely that they differed significantly from the Herefords in age. The lower body weight of the bison reflected their lower rate of gain during the winter in the feedlot. Daily gains in the 196-day feeding experiment averaged $2.05 \pm .18$, $1.86 \pm .25$ and $1.24 \pm .17$ lb. for the Herefords, Cattalo and bison, respectively.

As shown by Table 2, the Cattalo bulls varied more widely in body weight at the time of the temperature study than the Herefords and bison. Initial weights of the Cattalo on December 23, 1952, were also more variable than those of the other two lots. Coefficients of variation of initial weight were 12.7, 7.1 and 10.2 per cent for the Cattalo, Herefords and bison, respectively. Some of the Cattalo bulls were out of $\frac{1}{2}$-bison hybrid cows, which generally wean heavier calves than the other Cattalo or Hereford cows do, and this would contribute to the variation in initial weight of the Cattalo bulls. Coefficients of variation of daily gain in the winter feeding period were 13.3, 8.9 and 13.9 per cent for the Cattalo, Herefords and bison, respectively.

The larger variation of the Cattalo bulls in body weight would, perhaps, account in part for their greater variation in testis weight. However, there was evidence of a general relationship between testis weight and

sperm production. The testes of sterile Cattalo bulls were, on the average, 37.8 grams lighter in weight than those of the Cattalo bulls in which some sperm production was found.

Cattalo bulls might be expected to vary in testis weight at one year of age as a result of variation in the degree of their sexual maturity, if it is true that bison bulls do not reach puberty until two years of age. Some preliminary information on this point was obtained in 1953. Twelve sterile yearling bulls tested by unilateral castration and microscopic examination of epididymal smears in 1952, and one yearling bull that appeared to have a low degree of fertility, were given a second test in 1953 at two years of age by removal of the second testicle. Three older bulls that had shown various degrees of fertility by previous tests at one year of age were also tested again by this method. Complete conformity with the results of the yearling test was obtained, in so far as the presence or absence of spermatozoa was concerned.

Fertile Cattalo bulls appear to have more fully developed testes than have sterile Cattalo bulls. The sterile Cattalo bull which had the lowest testis weight recorded in this study was observed prior to the time of the temperature determinations to have very slender testes, although the scrotum did not appear to hold the testes abnormally close to the body.

Investigation with mature bison bulls is needed to determine with certainty whether spermatogenesis occurs in bison at a higher temperature than in domestic cattle. However, it is significant that the intra-testicular temperatures of Cattalo bulls were slightly lower, rather than higher, than those of Hereford bulls.

The rectal temperatures reported in Table 1 are quite high, when compared with published values. Gaalaas (5) found rectal temperatures of Jersey cattle to range from 101.0° F. at an air temperature of 50° F. to 103.2° F. at an air temperature of 95° F. Kibler and Brody (7) studied effects of increasing environmental temperature from 50° F. to 105° F. and of decreasing environmental temperature from 50° F. to 9° F. Rectal temperatures began to rise in Jerseys and Holsteins at about 75° F. environmental temperature. Decreasing environmental temperature from 50° F. to 9° F. caused no significant change in rectal temperature. The maximum environmental temperature during the July, 1953, studies reported herein was 75° F.

Hewitt (6) found the average rectal temperature of 70 Hereford cattle to be 101° F., with a range from 98.0° F. to 102.4° F. The temperatures were taken after the cattle were stabled for one day. The range of rectal temperatures on the first day of stabling, when the animals were in a greater state of excitation, was 100.4° F. to 103.6° F., with an average of 101.8° F.

The bison, Cattalo and Herefords used in the Manyberries experiment were all unaccustomed to the restriction of the squeeze chute; they had been raised on the range and wintered on a group-feeding basis in open pens. The bison were extremely excitable, and the Cattalo were also more excitable than the Herefords. Excitability may have been partly responsible for the rather high rectal temperatures of these cattle and the

difference between the groups in the degree of their excitation may have contributed to the differences between them in mean rectal temperature.

Williams *et al.* (10) found a slight, negative regression of rectal temperature on body weight. The regression was −.093° F. per 100 pounds of body weight in Hereford bull calves and −.020° F. per 100 lb. of body weight in Angus bull calves (the latter figure was not statistically significant). The Cattalo and Herefords used in the present study did not differ significantly in body weight. The bison were considerably lighter in body weight than the Cattalo and Herefords, but there is not enough known about the growth-body temperature relationship in bison to permit a conclusion as to the influence their lower body weight may have had on the degree by which their rectal temperatures exceeded those of the Cattalo and Herefords. In fact, there was a non-significant, positive correlation ($r = 0.310$) between body weight and rectal temperature within the bison group.

Further comparative studies on the physiology of reproduction in bison, Cattalo and Herefords are warranted. Eventual recovery of fertility in animals which combine desirable characteristics of two reproductively isolated species has practical possibilities, particularly in the production of strains better adapted to unfavourable environments.

ACKNOWLEDGEMENT

A. A. Ingram, Cattle Herdsman at the Manyberries (Alberta) Range Experimental Farm, assisted in the determination of intra-testicular temperatures.

REFERENCES

1. Cupps, P. T., R. C. Laben, and S. W. Mead. The relation of certain semen-quality tests to breeding efficiency and characteristics of semen from low-fertility bulls before and after hormone injection. J. Dairy Sci. 36 : 422-426. 1953.
2. Cupps, P. T., R. C. Laben, and S. W. Mead. Histology of the pituitary, testis, and adrenal in relation to reproduction in the bull. J. Dairy Sci. 37 : 1074-1087. 1954.
3. Deakin, Alan, G. W. Muir, and A. G. Smith. Hybridization of domestic cattle, bison and yak. Pub. 479, Can. Dept. Agr. 1935.
4. Dobzhansky, Th. Studies on hybrid sterility. I. Spermatogenesis in pure and hybrid Drosophila pseudoobscura. Zeit. f. Zellforsch. u. Microskop. Anat. 21 : 169-223. 1934.
5. Gaalaas, R. F. Effect of atmospheric temperature on body temperature and respiration rate of Jersey cattle. J. Dairy Sci. 28 : 555-563. 1945.
6. Hewitt, A. E. A preliminary study of the normal variation in the temperature of cattle. J. Amer. Vet. Med. Assoc. 11 : 544-548. 1921.
7. Kibler, H. H., and Samuel Brody. Environmental physiology with special reference to domestic animals. XI. Effects of temperature, 50° to 105° F. and 50° to 9° F. on heat production and cardiorespiratory activities in Brahman, Jersey and Holstein cows. Missouri Research Bull. 464. 1950.
8. Moree, R. Genic sterility in inter-specific male hybrids of Peromyscus. Anat. Rec. 96 (4) : 66 (Abstract). 1946.
9. Turner, C. D. General endocrinology. W. B. Saunders Co., Philadelphia, Pa. 1948.
10. Williams, C. M., Hugo Krueger, and Ralph Bogart. Rectal temperatures on performance tested beef calves. Proc. Amer. Soc. Animal Prod. 4. 1953.

GROWTH DEPRESSING FACTORS IN RAPESEED OILMEAL

II. STUDIES ON COUNTERACTION BY DIETARY SUPPLEMENTS

J. M. Bell[1] and Elinor Baker[2]

University of Saskatchewan, Saskatoon, Sask.

[Received for publication June 25, 1956]

ABSTRACT

Five experiments were reported, involving a total of over 350 mice, in feeding trials concerned mainly with growth rates and feed utilization. One experiment involved gestation-lactation performance of mice fed rapeseed oilmeal as a ration component.

Proportions of rapeseed oilmeal ranged from 17 to 50 per cent of the diet. The feeding of iodinated casein or of potassium iodide failed to counteract the growth-depressant factor in rapeseed oilmeal. Aureomycin as a feed supplement was ineffective against the factor.

Growth, tissue composition and lactation data confirmed the deleterious nature of high levels of rapeseed oilmeal in the ration and provided evidence that species and sex differences in response to the rapeseed oilmeal factor exist. Males appeared to be more severely affected than females. Mice did not respond to iodine and to iodinated casein as has been reported for chickens and turkeys.

INTRODUCTION

Evidence for the existence of a toxic factor or factors in rapeseed oilmeal has been well established, but the methods of action and counteraction of the factor are less clear (3). In particular there appear to be distinct species differences in responses to iodinated casein and to iodide supplements used in conjunction with rapeseed oilmeal rations.

This report contains the results of five experiments with mice in which tests have been made of (a) limiting the levels of rapeseed oilmeal; (b) antibiotic feed supplements; (c) iodinated casein; (d) potassium iodide supplements; (e) effects of rapeseed oilmeal on reproduction, and (f) rapeseed oilmeal in comparison with thiourea and thiouracil as goitrogenic growth inhibitors.

MATERIALS AND METHODS

Experiment No. 1.

This experiment was designed (i) to test the efficacy of 0.05 per cent Protamone[3] (iodinated casein) since higher levels (0.1 and 0.5 per cent) (4) had depressed growth of mice; (ii) to test the value of supplemental iodide at a 0.001 per cent I level as potassium iodide and as potassium iodide-calcium stearate; (iii) to test the value of an aureomycin feed supplement (0.1 per cent Aurofac[4]); (iv) to obtain further information on the effects of limiting the proportion of rapeseed oilmeal in the ration by the substitution of either linseed oilmeal or meat meal to provide 50 per cent of the supplementary protein, and (v) to test combinations of Protamone, iodide and aureomycin treatments in a factorial design with each of the three rapeseed oilmeal-containing diets.

The basal diet formula for the lots not receiving linseed oilmeal or meat meal was: wheat 72.57; rapeseed oilmeal 22.43; brewers' dried

[1] Professor, Head, Department of Animal Husbandry, University of Saskatchewan, Saskatoon, Sask.
[2] Formerly technician, Department of Animal Husbandry.
[3] Courtesy, Cerophyll Laboratories Inc., Kansas City, Mo.
[4] Courtesy Lederle Laboratories Division, Pearl River, N.Y. Aurofac contains >1.8 gm. aureomycin (chlortetracycline) and 1.8 gm. vitamin B_{12} per pound.

yeast 1.00; Vitagrass (dehydrated cereal grass) 1.00 per cent, and a vitamin A, D and E oil supplement (4). In the diets containing linseed oilmeal the formula was changed to: wheat 71.45; rapeseed oilmeal 11.43, and linseed oilmeal 12.12 per cent. The vitamin supplements remained unchanged. The diets substituted with meat meal were: wheat 77.80; rapeseed oilmeal 10.20, and meat meal 7.00 per cent; vitamin supplements again remaining the same.

Mineral supplements were added to portions of the above basal diets. Rations containing no supplemental iodine had 3 per cent of the following mixture added: bone meal 140, ground limestone 235, salt 125, $FeSO_4.7H_2O$ 10, $MgSO_4.7H_2O$ 10, $MnSO_4.4H_2O$ 0.25 and $CuSO_4.5H_2O$ 0.25 grams. Those diets containing potassium iodide had 0.047 per cent KI added to the mineral mixture and those containing the stabilized iodide had 0.052 per cent KI-Ca stearate added to the mineral mixture, both to provide 0.001 per cent I.

Aurofac and Protamone were added to provide 1.0 and 0.05 per cent respectively of the final mixtures according to the experimental design. All diets contained 20 per cent protein. Four male mice were randomly allotted to each diet.

Experiment No. 2.

This experiment was designed originally to test with swine the earlier findings relative to limitation of the level of rapeseed oilmeal and particularly the use of antibiotic feed supplements and KI. Simultaneous studies with mice were to be conducted but, because of a disease outbreak in the swine, the results were ultimately confined to the mice.

Two diets were fed to the mice—a control ration and a rapeseed oilmeal ration. The formula of the control ration was: wheat 39.6, oats 39.6, soybean oilmeal 13.6, meat and bone scrap 3.2, alfalfa meal 3.0, ground limestone 0.7, iodized salt 0.5 per cent, aureomycin[1] 10 gm./ton and synthetic vitamins A and D to meet N.R.C. (9) allowances.

The composition of the rapeseed oilmeal ration was: wheat 34.75, oats 34.75, rapeseed oilmeal 17.10, meat and bone scrap 3.4, alfalfa meal 3.0, ground limestone 0.7, salt 0.5 per cent, aureomycin 10 p.p.m., KI-calcium stearate 1 gm./100 lb. ration, and vitamin A and D as before. Both rations contained about 18 per cent crude protein.

Ten weanling mice of each sex were allotted at random to each diet. Feed consumption records were kept and at the termination of the growth test the mice were skinned and eviscerated; their tails were removed and their legs severed at the hocks and elbows. Carcass weight was obtained and the carcass was then dried 24 hours at 105°C., before ash, protein and fat determinations were made. Thus information was sought relative to the effects of rapeseed oilmeal on body composition.

Experiment No. 3.

The object of this test was to compare the effects of propyl-thiouracil, thiourea and 1-5-vinyl-2-thiooxazolidone[2] with those of rapeseed oilmeal in the ration.

[1] Aureomycin T.-F., Courtesy Lederle Laboratories Division, Pearl River, N.Y.
[2] Synthesized by J. M. Raciszewski, E.Y. Spencer, and L. W. Trevoy, Chemistry Department, University of Saskatchewan, Saskatoon, Sask.

The basal diet was composed of wheat 23, oat meal 20, vitagrass 2, brewers' dried yeast 2, minerals (iodine-free) 3 per cent, and vitamins A and D as before. The protein supplements constituted 50 per cent of the weight of the rations and were: (a) rapeseed oilmeal; (b) soybean oilmeal + linseed oilmeal in equal parts by weight; (c) 'b' plus 0.1 per cent thiouracil; (d) 'b' plus 0.05 per cent thiourea, and (e) 'b' plus 0.002 per cent thiooxazolidone. To these five main rations each of four cross-treatments was applied in a simple factorial-type design. These cross-treatments were: (a) nil; (b) 0.003 per cent I as KI-calcium stearate; (c) Protamone at 0.01 per cent, and (d) cortisone[1] orally at the rate of 2 mg./280 grams of diet.

Four weanling male mice were randomly allotted to the diets and growth and feed records were kept.

Experiment No. 4.

Five virgin and five multiparous female mice were fed a diet containing rapeseed oilmeal and similar groups were fed the standard stock colony diet for a period extending from 10 days prior to breeding until the young were weaned. The study was designed to gain further information on the effects of the rapeseed oilmeal factor on reproduction. The males were rotated daily between cages containing five females to guard against infertility of the male affecting the study; the males were removed 16 days after breeding commenced and the females were then placed in individual maternity cages.

Records were kept of parturition dates, number of young born and weaned, weaning weights, reproductive failures and mortality.

The control ration had the formula: wheat 21.85; oat groats 20.00; wheat bran 10.00; alfalfa meal 5.00; linseed oilmeal 15.00; meat scraps 15.00; bone meal 1.00; ground limestone 1.00; iodized salt 1.00; $MnSO_4 \cdot 7H_2O$ 0.025, feeding fish oil (1800A–400D) 0.15 per cent.

The rapeseed oilmeal ration was composed of: wheat 24; oat meal 24; vitagrass 2; wheat bran 10; rapeseed oilmeal 30; fish meal 5; bone meal 2; iodized salt 1; brewers' dried yeast 2 per cent, and vitamins A and D.

Experiment No. 5.

Because of inability to obtain, in previous experiments, a favourable response to iodinated casein, as had been reported by Blakely and Anderson (7), a test involving several levels of Protamone was designed. The levels 0.0, 0.01, 0.02, 0.04, 0.08, 0.16 and 0.32 per cent were used with both a control diet and a diet containing 50 per cent of Argentine rapeseed oilmeal. Three male and three female weanling mice were randomly allotted to each of the 14 different rations. Feeding and management were similar to that used in the other growth trials.

The rapeseed oilmeal diet had the formula: barley 20; wheat 20; brewers' dried yeast 2; alfalfa meal 5; minerals 3, and rapeseed oilmeal 50 per cent. Vitamins A and D were added as before.

The control diet was: barley 30; wheat 30; brewers' dried yeast 3; alfalfa meal 7.5; minerals 4.5; linseed oilmeal 12.5, and meat meal 12.5 per cent. Vitamins A and D were added.

[1] Courtesy, Merck and Co. Ltd., Montreal, Que.

Animal Management

Mice of Carworth No. 1 strain were used in these studies. For the growth trials male mice weighing 7.5 to 8.5 grams, not exceeding 22 days of age, and female mice weighing 7.0 to 8.0 grams and of similar age were randomly allotted both to diets and to individual wire-bottomed metal cages. Feed and water were provided *ad libitum*, and the laboratory temperature was thermostatically maintained.

Accurate feed records were kept with the aid of a special feeder designed to prevent wastage by the mice. Weight gain and feed records were kept during a 14-day assay period.

RESULTS AND DISCUSSION

Experiment No. 1

Statistical analyses revealed significant effects by all of the experimental variables on the observed weight gains of the mice as well as a significant stimulatory effect of Protamone upon feed intake. However, since covariance analysis of feed and gains indicated a highly significant relationship ($r = 0.454$) between the two, the gains were adjusted and are presented in Table 1.

The general result of diluting the rapeseed oilmeal with either linseed oilmeal or meat meal was favourable. Protamone, as in earlier work (4), caused depression of gains, in spite of the significant increase that occurred in feed consumption. Thus, either the level used was unsatisfactory or this procedure does not constitute a satisfactory method of counteracting the rapeseed growth inhibitor. The general effect of iodine treatments was nil, but the interaction between protein supplements and iodine treatments indicated that KI-calcium stearate was of value with the straight rapeseed oilmeal supplement and with the combination of

TABLE 1.—EFFECTS OF PROTAMONE, POTASSIUM IODIDE AND AUROFAC IN RATIONS CONTAINING VARIOUS LEVELS OF RAPESEED OILMEAL, IN CONJUNCTION WITH VEGETABLE- AND ANIMAL-ORIGIN PROTEINS, ON GROWTH OF WEANLING MALE MICE

Treatments	No. of mice	Nec. diff. P = 0.05	Protein supplements		
			Rapeseed oilmeal	Rapeseed oilmeal + linseed oilmeal	Rapeseed oilmeal + meat meal
		gm.	gm.	gm.	gm.
Controls	48	0.50	11.06	12.14	12.18
Nil	24	0.70	11.94	12.67	12.54
Protamone (0.05%)	24		10.18	11.61	11.82
Nil	16	0.86	10.98	11.77	12.28
KI	16		10.48	11.95	12.60
KI—Ca stearate	16		12.34	12.70	11.66
Nil	24	0.70	10.41	11.60	11.68
Aurofac	24		11.71	12.71	12.68
No aurofac, no protamone	12	0.99	11.54	12.45	11.55
No aurofac, + protamone	12		9.29	10.73	11.80
Aurofac, no protamone	12		12.34	12.88	13.51
Aurofac, + protamone	12		11.08	12.49	11.85

rapeseed oilmeal + linseed oilmeal. It would appear that the KI may have been ineffective because of loss of iodine by volatilization.

Aurofac proved beneficial with every type of protein supplement. It promoted superior gains without a corresponding increase in feed consumption.

Since there was a significant interaction effect between types of protein supplement, Aurofac and Protamone, the final evaluation of the component treatments must be made from the last four lines of Table 1. When the diets were supplemented with rapeseed oilmeal alone it is obvious that the previously noted depressive effect of Protamone occurred with or without added Aurofac in the ration. The combining of Protamone and Aurofac resulted in a cancellation of the typical Aurofac effect.

With rapeseed oilmeal + linseed oilmeal rations, Protamone depressed gains significantly only in the absence of Aurofac. It might be concluded that aureomycin *per se* has been of no value in those rations devoid of animal-origin protein, the real effect being a counteraction of the depressive effects of Protamone. The only simple response to Aurofac occurred in the diets containing meat meal. Again the value of the aureomycin was cancelled by the Protamone.

This experiment has provided evidence in favour of iodine supplementation and against Protamone and the feed supplement Aurofac as means of counteracting the rapeseed oilmeal growth inhibitor(s).

Experiment No. 2

The feeding trial data from this experiment showed no differences in feed intakes or in rates of gain on comparing a control ration with one containing rapeseed oilmeal at a 17 per cent level (Table 2). The fact that the gains were generally lower than in Experiment No. 1 may be attributable to an apparently lower energy value of the feed in this case, although data from the two studies are not directly comparable.

A depression in gain that approaches statistical significance (at $P = 0.05$) occurred in males that received the rapeseed oilmeal ration. Evidence of a real effect may be seen in the comparative study of body composition. Whereas females showed no apparent effect in terms of gains, feed intake, body water, fat, protein or ash, the males have shown a trend towards having more water with less fat and protein. It is difficult to determine,

TABLE 2.—EFFECTS OF RAPESEED OILMEAL RATIONS ON GROWTH, FEED CONSUMPTION AND BODY COMPOSITION OF MALE AND FEMALE MICE

Treatment	Sex	Gain[1]	Feed[2]	Carcass composition			
				Water	Fat	Protein	Ash
		gm.	gm.	%	%	%	%
Control	Male	9.4	46.0	70.3	3.6	20.1	5.5
	Female	8.0	43.6	71.0	3.6	19.6	5.6
Rapeseed oilmeal	Male	8.2	43.0	72.1	2.8	18.6	5.5
	Female	8.0	43.6	70.6	3.7	19.0	5.7

[1] Necessary difference at $P = 0.05$ for gains is 1.0 gram.
[2] Necessary difference at $P = 0.05$ for feed is 4.0 grams.

from these data, whether or not these tissue composition differences are complicated by normal maturation effects, but it seems clear that the sexes of mice respond differently to rapeseed oilmeal, males being more markedly affected than females.

In terms of growth and feed intake, this study indicates that limited amounts of rapeseed oilmeal can be used in practical-type rations containing KI, aureomycin and meat meal. However, the general level of gains obtained and the observed effects on body composition suggest that 17 per cent rapeseed oilmeal, even with the supplements tested, may have deleterious effects on animals and may affect males more seriously than females.

Experiment No. 3

The results of this study of the effects of various 'hormone' and iodine treatments on goitrogenic diets are shown in Table 3. There were effects on feed intake noted in several cases and there was a highly significant correlation ($r = 0.714$, 59 D.F.) between feed intake and gains. The adjustment of the gains in accordance with the observed regression revealed that the effect of Protamone, in general, was directly related to the increased feed intake, whereas the difference in growth responses to the rapeseed oilmeal and the soybean oilmeal + linseed oilmeal diets remained significant despite statistical equalization of feed intakes. The effect of the growth depression factor is evident. It appears to decrease the efficiency of feed utilization.

The added thiooxazolidone had no effect on either feed intake or rate of gain. It is possible that the amount used was too low to obtain the desired comparison of thiooxazolidone with the natural rapeseed oilmeal factor. Wetter and McConnell* have found isothiocyante contents varying from 0.3 to 1.4 per cent in solvent-extracted rapeseed oilmeals, whereas only 0.002 per cent of thiooxazolidone was used in the diets of this experiment.

Thiouracil and thiourea reduced the gains to a level comparable to those obtained with the rapeseed oilmeal diet, and in fact, significantly lower, as noted in the interaction effects in Table 3.

Iodine at a level of 0.003 per cent (as KI-calcium stearate) had no effect on either the rapeseed oilmeal or any of the other goitrogenic diets. This is in contrast to the results of Experiment No. 1 in which 0.001 per cent iodine from the same source was used. However, in Experiment No. 1 only 22 per cent rapeseed oilmeal was used as compared to 50 per cent in Experiment No. 3. It is suggested that iodine may be of some, but definitely limited, value in counteracting the growth depression factor in rapeseed oilmeal.

Protamone again proved to have adverse effects in conjunction with rapeseed oilmeal, since it reduced the adjusted gains from 9.5 to 7.7 grams. It seems improbable that the 0.01 per cent level was too high in view of its behaviour in the soybean oilmeal + linseed oilmeal diets. It had no effect in the absence of added goitrogens but it counteracted the thiouracil added. Protamone had no value in relation to thiourea or thiooxazolidone at the

* Wetter, L. R., and W. McConnell. *Private communication.* 1955.

TABLE 3.—EFFECTS OF DIETARY IODINE, PROTAMONE AND CORTISONE ON MICE FED VARIOUS GOITROGENIC RATIONS

Treatment	No. mice per group	Gains	Feed intake	Adjusted gains
		gm.	gm.	gm.
Basal Rations				
Necessary difference		*1.3*	*4*	*0.9*
Rapeseed oilmeal	16	8.5	36	8.6
Soybean oilmeal + linseed oilmeal	16	11.2	40	10.3
Soy + L.O.M. + thiouracil	16	7.1	33	7.9
Soy + L.O.M. + thiourea	16	7.4	34	8.0
Soy + L.O.M. + thiooxazolidone	16	10.6	40	9.7
Treatments				
Necessary difference		*1.2*	*3*	*0.8*
Nil	20	8.6	36	8.7
Iodine	20	8.7	35	9.0
Protamone	20	9.9	40	9.0
Cortisone	20	8.6	35	8.9
Interaction Effects				
Necessary difference		*2.6*	*8*	*1.8*
Rapeseed oilmeal				
+ nil	4	8.9	34	9.5
+ iodine	4	9.3	37	9.2
+ protamone	4	8.3	39	7.7
+ cortisone	4	7.5	32	8.9
Soy + L.O.M.				
+ nil	4	10.5	39	9.9
+ iodine	4	12.4	41	11.3
+ protamone	4	10.8	40	9.9
+ cortisone	4	11.1	39	10.5
Soy + L.O.M. + thiouracil				
+ nil	4	5.2	29	7.0
+ iodine	4	5.6	29	7.4
+ protamone	4	11.6	42	10.3
+ cortisone	4	5.8	31	7.1
Soy + L.O.M. + thiourea				
+ nil	4	7.5	37	7.4
+ iodine	4	5.6	27	7.8
+ protamone	4	8.8	39	8.2
+ cortisone	4	7.7	33	8.5
Soy + L.O.M. + thiooxazolidone				
+ nil	4	10.9	39	10.3
+ iodine	4	10.6	39	10.0
+ protamone	4	10.1	41	9.0
+ cortisone	4	10.9	41	9.8

levels tested. These observations indicate that the rapeseed goitrogen does not resemble thiouracil in its action but may resemble thiourea. This agrees with Astwood (1).

The dietary administration of about 0.5 mg. of cortisone per mouse daily proved to be without effects on either gains or feed intakes under any of the conditions tested. It would be of interest to investigate the effects of cortisone injections in view of the apparent endocrine involvements of rapeseed oilmeal.

TABLE 4.—REPRODUCTION RESPONSES OF FEMALE MICE FED DIETS CONTAINING RAPESEED OILMEAL COMPARED WITH MICE FED THE STOCK DIET

Rations	Females	Number born	Days to parturition	Av. no. per litter	Av. no. weaned	Av. weight at weaning (gm.)	Mortality of dams post-partum (no.)
Control	Virgin	4	26	9.2	8.5	7.4	0
	Multiparous	2	32	12.5	9.5	6.8	1
Rapeseed oilmeal	Virgin	5	30	8.8	5.0	7.2	2
	Multiparous	3	23	9.0	4.3	7.7	1*

* Two females displayed cannibalism, a type of behaviour occasionally observed in the stock colony among aged females.

Experiment No. 4

In the limited study of the effects of rapeseed oilmeal on female reproduction (Table 4) about 50 per cent of the aged females on both rations failed to produce a litter but the breeding of the young females appeared to be satisfactory. Likewise the number of young mice per litter was not reduced appreciably by the rapeseed oilmeal diet. It did appear that the number of young weaned was significantly lower with those mice fed rapeseed oilmeal. Two young mothers and one aged one died during the lactation period and several showed evidence of cannibalism on the rapeseed oilmeal diet. Those young mice whose mothers survived the test were weaned at near normal weights, which suggests that lactation was not adversely affected, but it would seem that the use of 30 per cent rapeseed oilmeal in lactation rations imposed sufficient additional stress to interfere with normal performance: growth and lactation in young females and lactation in aged, partially depleted females.

Experiment No. 5

The results of feeding levels of Protamone ranging from 0 to 0.32 per cent of the diet are shown in Table 5. Typical differences were found between sexes and between control and rapeseed oilmeal rations as far as growth rates were concerned, the necessary difference in weight gain being 1.0 gram ($P = 0.05$).

The effects of Protamone varied depending on the type of ration used In the case of the control ration, levels as high as 0.32 per cent did not depress growth and there is a suggestion that the lower levels actually stimulated feed intakes and gains. The necessary difference for gains was 2.6 grams. When Protamone was fed in conjunction with rapeseed oilmeal rations, severe growth inhibition occurred. A significant depression in gains occurred at or before the 0.02 per cent level and mortality was high as Protamone levels increased beyond this level. A level of 0.50 per cent was also tested (4) with similar results. Thus it appears to be definite that iodinated casein does not at any level of intake constitute a counteractive measure for the factor present in rapeseed oilmeal as far as the mouse is concerned. Of some significance is the fact that the mouse can tolerate much less iodinated casein when rapeseed oilmeal is fed. This may suggest a species difference (mice and turkeys) in metabolism involving the growth depressant and/or iodinated casein. The differences previously noted in response to iodine also should be recalled in this regard.

TABLE 5.—EFFECTS OF VARIOUS LEVELS OF PROTAMONE ON RESPONSES OF MALE AND FEMALE MICE FED CONTROL OR RAPESEED OILMEAL RATIONS

Treatment	Gains	Feed intakes[1]	Mortality
	gm.	gm.	%
Control + 0% protamone	9.1	45	0
0.01 protamone	11.7	54	0
0.02 protamone	10.7	54	0
0.04 protamone	9.8	53	0
0.08 protamone	10.1	55	0
0.16 protamone	8.6	56	0
0.32 protamone	8.9	58	0
Rapeseed oilmeal + 0% protamone	5.7	39	0
0.01 protamone	3.9	40	0
0.02 protamone	2.4	37	33
0.04 protamone	1.4	35	17
0.08 protamone	0.6	39	50
0.16 protamone	0.7	34	33
0.32 protamone	0.7	38	67
Control ration	9.8	54	0
Rapeseed oilmeal ration	2.2	38	28
Males	6.7	49	14
Females	5.4	44	14
Control ration, Males	11.0	58	0
Females	8.7	50	0
Rapeseed oilmeal ration, Males	2.3	48	28
Females	2.1	35	28

[1] Feed intakes calculated on the basis of survivors only.

The results of these five experiments with mice have revealed no method of fully counteracting the effects of the undesirable factor(s) in rapeseed oilmeal. Iodine effects have been variable but in no instance was its effect of the magnitude noted by Dow and Allen (8) for chicks. Further evidence for the existence of important species differences was provided by the finding that iodinated casein at various levels up to 0.5 per cent of the diet failed to counteract the growth depression due to rapeseed oilmeal. By contrast, Blakely and Anderson (7) found 0.022 per cent iodinated casein to be effective with turkey poults.

An antibiotic feed supplement was tested and found to be of no direct value in counteracting the growth inhibition due to rapeseed oilmeal.

Additional evidence on the mode of action of the rapeseed factor was obtained by the observation that iodinated casein counteracted the effects of thiouracil on growth but did not counteract the effect of thiourea or rapeseed oilmeal. Rapeseed oilmeal affected growth and tissue composition in males more severely than in females. Rapeseed oilmeal was found to be deleterious, at a 30 per cent level, to the health of female lactating mice. These observations lend support to the possibility that the rapeseed factor affects the endocrine system. The site of involvement is not clear from these data but since a goitrogen is apparently involved, and since iodinated casein and iodine have proven effective in fowl, it may be that tissue oxidation reactions (2, 6), rather than thyroxine synthesis, are affected in the mouse.

ACKNOWLEDGEMENTS

The authors acknowledge the financial assistance provided by the National Research Council of Canada through the Associate Committee on Animal Nutrition.

REFERENCES

1. Astwood, E. B. The natural occurrence of antithyroid compounds as a cause of simple goiter. Ann. Int. Med. 30 : 1087-1103. 1949.
2. Bach, E. Retardation of oxidation of ascorbic acid. II. Z. Vitaminforsch 12 : 289-297. 1942.
3. Bell, J. M. The nutritional value of rapeseed oilmeal: A review. Can. J. Agr. Sci. 35 : 242-251. 1955.
4. Bell. J. M. Growth depressing factors in rapeseed oilmeal. III. Studies on counteraction by steam processing, extraction and dietary supplements. Can. J. Animal Sci. 37 : 31-42. 1957.
5. Bell. J. M., and K. Williams. Growth depressing factors in rapeseed oilmeal. Can. J. Agr. Sci. 33 : 201-209. 1953.
6. Benda, L. The effect of allylic compounds on tissue respiration *in vitro*. Monatsh. 82 : 1094-1103. 1951.
7. Blakely, R. M., and R. W. Anderson. Studies with rapeseed oilcake meal. II. The effect of the inclusion of Protamone in the diet, on the thyroid enlargement induced by the feeding of rapeseed oilcake meal to turkey poults. Sci. Agr. 28 : 398-402. 1948.
8. Dow, D. S., and C. E. Allen. Rapeseed oilmeal in broiler rations with observations on the nature and control of its metabolic inhibitors. Can. J. Agr. Sci. 34: 607-613. 1954.
9. Nutrient requirements for swine. National Research Council, Washington, D.C. 1954.

GROWTH DEPRESSING FACTORS IN RAPESEED OILMEAL

III. STUDIES ON COUNTERACTION BY STEAM PROCESSING, EXTRACTION AND DIETARY SUPPLEMENTS

J. M. Bell[1]

University of Saskatchewan, Saskatoon, Sask.

[Received for publication June 25, 1956]

ABSTRACT

Four feeding and growth experiments have been conducted with mice that received diets containing rapeseed oil meal treated by various steam processings, by extractions with hot or cold water, by extractions with ether or alcohol, by partial or complete sterilization of the diet, and by acid hydrolysis of different fractions of rapeseed oil meal. The effects of supplemental iodine (0.01 and 0.003 per cent), iodinated casein (0.5 per cent), antibiotics, vitamin B_{12} and certain enzyme inhibitors were studied.

Steam cooking up to 15 lb. pressure for 20 minutes was of little value. Aureomycin at 50 p.p.m. or a combination of aureomycin and terramycin at 200 p.p.m. did not counteract the toxic factor but apparently enhanced vitamin B_{12} nutrition. Vitamin B_{12} effected some improvement. Water extraction, particularly with hot water, reduced the growth-inhibitor effect, as did hot alcohol extraction.

The feeding of 0.01 per cent I depressed growth in mice fed rapeseed oilmeal but 0.003 per cent I gave no response. Ionidated casein depressed growth. The enzyme inhibitors tested had no effect on gains or feed intakes.

A total of 408 mice was involved in the experiments.

INTRODUCTION

In previous reports (1, 3) it was shown that potassium iodide and iodinated casein did not protect mice against the rapeseed oilmeal toxic factor, in contrast to reports on turkeys, rats and chickens (4, 5, 6). Water extraction of the meal was only partially effective (1). An aureomycin feed supplement exerted no apparent effect against the growth depressant (3). Thus no method of satisfactorily counteracting or removing the toxic factor(s) from rapeseed oilmeal has been discovered as far as mouse nutrition is concerned. In view of the possibility of the existence of species differences in response to rapeseed oilmeal (2), it remains of interest to investigate the effects of the toxic factor(s) on the mouse.

The favourable, even though limited, response obtained to water extraction of rapeseed oilmeal directed interest to other extraction procedures. The experiments now reported included studies on the effects of extractions with hot water and cold water as well as extractions with ether and alcohol. Other approaches to the problem were aimed primarily at modifying the enzyme relationships affecting the release of the goitrogen from complex parent material. In this regard steam processing, acid hydrolysis, high levels of antibiotics and enzyme-inhibiting chemicals were tested as treatments for rations containing rapeseed oilmeal.

MATERIALS AND METHODS

Experiment No. 1

The objectives were to study the effects of various degrees of steam cooking of rapeseed oilmeal as a means of destroying its growth inhibition

[1] Professor, Head, Department of Animal Husbandry, University of Saskatchewan, Saskatoon, Sask.

properties and to determine the effects of supplementation with iodine, iodinated casein and aureomycin subsequent to steam treatments. Eight protein supplements were prepared: (i) linseed oilmeal as a control ration; (ii) rapeseed oilmeal (mixed origin, predominantly Argentine type); (iii) rapeseed oilmeal steamed 10 minutes at 5 lb. pressure; (iv) same at 10 lb. pressure; (v) same at 15 lb. pressure; (vi) rapeseed oilmeal steamed 20 minutes at 5 lb. pressure; (vii) same at 10 lb. pressure, and (viii) same at 15 lb. pressure.

As cross treatments in an 8 x 3 x 2 factorial design (a) nil, (b) 0.01 per cent iodine (as KI) and (c) 0.5 per cent Protamone[1] were added. Within each of these nil and Aurofac[2] to supply 50 p.p.m. aureomycin and about 18 mcg. vitamin B_{12} per pound were used.

Weanling female mice weighing 7 to 11 grams were allotted as described elsewhere. The basic formula for all the diets was as follows: wheat 42.8; alfalfa leaf meal 2.0; rapeseed oilmeal or linseed oilmeal 51.2; brewers' dried yeast 1.0; minerals 3.0 per cent, and a vitamin A, D and E oil. The mineral mixture was that described by Bell and Baker (3) except that iodine was omitted. The diets contained approximately 25 per cent protein.

Experiment No. 2

This test was designed as an $8\times2\times2\times2$ factorial in which there were eight protein sources, representing controls and various steam and extraction treatments of rapeseed oilmeal. The effects of vitamin B_{12}, antibiotics and iodine were again tested.

The sources of supplementary protein used in the rations to supply about 25 per cent protein in the final mixture were as follows:

(*a*) Soybean oilmeal and fishmeal (72 per cent protein) in equal parts. This was chosen as a high quality supplement in order to promote normal growth in the positive control series.

(*b*) Rapeseed oilmeal, predominantly of Argentine type and of ordinary commercial quality.

(*c*) Rapeseed oilmeal that had been steam cooked for 30 minutes at 15 lb. pressure, air-dried and reground before use.

(*d*) Water-extracted rapeseed oilmeal. This was prepared by soaking rapeseed oilmeal overnight in 2.5 times its weight of water at room temperature, filtering by suction, washing the residue with approximately the same quantity of water as previously used and finally drying in shallow trays at room temperature.

(*e*) Steamed, extracted rapeseed oilmeal. A quantity of rapeseed oilmeal was steamed for 30 minutes at 15 lb. pressure and processed as in (d) above.

(*f*) Soaked rapeseed oilmeal. This material was processed as in (*d*) except that the liquid was reincorporated prior to drying.

(*g*) Water extracted rapeseed oilmeal + steamed extract. This was prepared by extracting with water as in (*d*) and then processing the extract with steam for 30 minutes at 15 lb. pressure. The extract was then recombined with the residue and the whole dried and ground as before.

[1] Courtesy, Cerophyll Laboratories, Inc., Kansas City, Mo.
[2] Courtesy, Lederle Laboratories Division, Pearl River, N.Y. Aurofac contains 1.8 gm. aureomycin chlortetracycline) and 1.8 mg. vitamin B_{12} per pound.

(*h*) Extracted rapeseed oilmeal + hydrolyzed extract. An extract from 2000 grams of rapeseed oilmeal was obtained as in (*d*); 300 ml. concentrated HCl was added and the mixture was boiled gently for 10 minutes. After cooking, the solution was neutralized with Na_2CO_3, filtered, and added to the residue, mixed and dried.

The vitamin B_{12} supplement was provided by adding a solution made of 0.8 mg. crystalline vitamin B_{12}[1] to 200 ml. distilled water. The amount of the vitamin added to the diet was 50 micrograms per kilogram of complete ration.

The antibiotic supplement was composed of crystalline aureomycin-HCl[2] 1.28 gm., terramycin-HCl[3] 1.28 gm. and sucrose 29.44 gm. This mixture was added to provide 200 p.p.m. of total antibiotics in the rations.

Iodine was provided in a mineral mixture as described by Bell and Williams (1) to allow 0.01 per cent in the treated rations. The source was KI-calcium stearate.

All rations contained wheat as the main energy source and also contained 2 per cent alfalfa leaf meal, 1 per cent brewers' yeast, 3 per cent minerals and vitamins A, D and E. The proportion of wheat was varied depending on the protein source in order to maintain the protein level of approximately 25 per cent.

Three male weanling mice were randomly allotted to each diet and to individual wire-bottomed cages for 14-day feeding trials. At the end of this test mice representing different treatments were killed for thyroid examination. A rating system for gross appearance of the gland was thus developed and one mouse from each treatment was then examined and rated either 1, 2, 3 or 4. A rating of 1 was normal, based on the positive controls, and 4 represented a gland showing obvious enlargement and/or marked hyperemia.

Experiment No. 3

This study was an attempt to evaluate other extraction and moist-heat treatments of rapeseed oilmeal, as well as another test on the efficacy of iodine. The latter was to check the value of iodine at a much lower level than that previously used.

The design of this trial was a simple 2 × 7 factorial with seven protein supplements each tested without added iodide and with 0.003 per cent iodine (KI-calcium stearate). The basal diet was composed of wheat 28.6; oats 14.3; Vitagrass 2.0; brewers' dried yeast 2.0; minerals (I-free) 3; aureomycin T.-F. 0.1[4]; vitamins A, D and E and protein supplement 50.0 per cent. The antibiotic level in the rations was 10 p.p.m. and the protein level was about 25 per cent. The protein supplements were as follows:

(*a*) Standard commercial rapeseed oilmeal, predominantly of Argentine type; untreated.

(*b*) Rapeseed oilmeal extracted with water. One part of rapeseed oilmeal and five parts of water were mixed and then stirred occasionally over a period of 26 hours at 26°C. At this time the mixture was

[1] Courtesy, Merck and Co. Ltd., Montreal, Que.
[2] Courtesy, Lederle Laboratories Division, Pearl River, N.Y.
[3] Courtesy, Chas. Pfizer and Co. Inc., Chicago, Ill.—Oxytetracycline-HCl.
[4] Courtesy, Lederle Laboratories Division, Pearl River, N.Y.

filtered through cheesecloth and then the extraction was repeated. The residue was dried at 26°C. and re-ground for incorporation into the rations.

(*c*) Rapeseed oilmeal treated as above except that ground, germinated rapeseeds were added during the soaking periods. The object of this treatment was to determine whether *Brassica* enzymes supplied by the germinating seeds would facilitate the release of thiooxazolidone from its parent glycoside complex and thereby effect a better extraction of the toxic factor.

(*d*) Rapeseed oilmeal solvent extracted seven times by soxhlet apparatus using 95 per cent peroxide-free ethyl alcohol in the presence of pyrogallol.

(*e*) Standard rapeseed oilmeal as in (*a*) but the complete diet, less the iodide and the antibiotic which were added later, was 'sterilized' with 15 lb. steam pressure for 15 minutes. This treatment was designed to destroy enzymes that might exist in the ration ingredients and which might otherwise affect the absorption or release of the toxic factor.

(*f*) Basal diet alone sterilized. This treatment was similar to (*e*) except that the rapeseed oilmeal was not sterilized.

(*g*) This was a positive control ration containing as the protein supplement a mixture of soybean oilmeal 91 to corn starch 9 parts. Only the basal portion was steam treated, leaving the soybean oilmeal and starch unheated.

Male weanling mice were employed for this experiment in 14-day growth trials and accurate records were kept of feed intakes. The systems of allotment and management have been described previously. Five animals were employed for each ration.

Experiment No. 4

Grussendorf* reported that hot water extraction of rapeseed oilmeal was effective in removing the toxic principle and that rapeseed oilmeal has been used successfully in Europe as an ingredient of silage. Among the possible detoxifying factors and procedures tested in this experiment were hot water extraction and acid hydrolysis. The effect of hot alcohol extraction as suggested by Matet *et al.* (7) was also investigated. One ration included allyl isothiocyanate, a goitrogen indicated to be present by the latter investigators and shown to occur in rapeseed oilmeal at levels varying from 0.3 to 1.4 per cent**.

Six types of protein supplements were employed in a simple factorial design:

(*a*) Rapeseed oilmeal commercially prepared from almost pure Argentine type.

(*b*) Rapeseed oilmeal as above but acid hydrolyzed by adding four times its weight of 1 per cent HCl in water. The mixture was stirred occasionally and held at 40°C. for 15-18 hours, then filtered and washed three times with distilled water, the last washing of which contained 1 per cent of Na_2CO_3 to neutralize any remaining HCl.

* Grussendorf, W. *Private communication.* 1953.
** Wetter, L. R., and W. McConnell. *Private communication.* 1955.

The residue was dried in shallow trays at room temperature with the aid of a fan.

(*c*) Rapeseed oilmeal extracted with hot 95 per cent ethyl alcohol. The meal was held at 70°C. in twice its weight of alcohol for 4 hours with frequent stirring. The material was then filtered and washed with twice the original amount of alcohol. The residue was then dried as above.

(*d*) Rapeseed oilmeal extracted with hot water. The meal was held at 80-100°C. for 45 minutes in four times its weight of water, with occasional stirring. The mixture was then filtered and washed with twice the original volume of hot water and the residue was dried as before.

(*e*) Soybean oilmeal and meat meal in equal parts to provide a control ration.

(*f*) Soybean oilmeal and meat meal as above but with allyl isothiocyanate added to provide 0.05 per cent in the diet. This level was based on the work of Viehover *et al.* (9) and was perhaps too low in view of more recent work. A small quantity of a commercial feed flavour[1] was used to mask the acrid taste of the isothiocyanate.

The cross-treatments in this experiment were designed to study the possibility that certain enzyme inhibitors might be found which would delay the release of the goitrogen from its natural complex. Thus five treatments were employed: (i) Nil; (ii) 0.075 per cent $CuSO_4$; (iii) 0.02 per cent 3-nitro phenylarsonic acid; (iv) 0.02 per cent $AgNO_3$, and (v) 0.02 per cent NaF in the complete diet.

The basal diet was made of barley 40; wheat 40; brewers' dried yeast 4; alfalfa meal 10; minerals (1) 6 per cent. This was mixed in equal parts with the various rapeseed oilmeals or with the soybean oilmeal-meal mixtures to provide a comparable level of protein. Vitamins A and D were added.

The feeding and management of the mice were similar to that in the previous experiment. Four male weanlings were allotted to each test ration.

RESULTS AND DISCUSSION

Experiment No. 1—(Steam processing)

The gains obtained in the 14-day growth trial with female mice are shown in Table 1. Rapeseed oilmeal diets proved to be inferior to the linseed oilmeal diets and the general effect of steam treatments was insignificant.

There was a statistically significant interaction between the antibiotic treatments and the protein supplements. The interaction data shown in the Table indicate that Aurofac stimulated growth of mice fed diets containing linseed oilmeal and the four most severe steam treatments, but not those fed the untreated rapeseed oilmeal or meals processed for 10 minutes at 5 or 10 lb. pressure.

The responses to iodine were generally favourable but iodine by itself did not permit normal gains in any instance. The highest individual gains in the experiment were found in those groups receiving both iodine and Aurofac but again none of the responses indicated complete counteraction of the growth inhibitor.

[1] Courtesy, Flavor Corporation of America, Chicago, Ill.

TABLE 1.—THE EFFECTS OF STEAM TREATMENTS, IODINE, IODINATED CASEIN AND ANTIBIOTICS ON GROWTH OF MICE FED RAPESEED OILMEAL DIETS (Experiment 1)

Treatment	No. of mice	Average gain	Nec. diff. (P = .05)
Processing treatments			
Linseed oilmeal	12	7.3	
Rapeseed oilmeal	12	4.3	
Rapeseed oilmeal, steamed			
10 min. @ 5 lb.	12	4.6	
10 min. @ 10 lb.	12	4.0	1.2
10 min. @ 15 lb.	12	4.4	
20 min. @ 5 lb.	12	5.1	
20 min. @ 10 lb.	12	5.4	
20 min. @ 15 lb.	12	4.7	
Thyroid treatments			
Nil	32	5.9	
Iodine, 0.01%	32	7.2	0.7
Iodinated casein, 0.5%	32	1.9	
Antibiotic-B_{12} treatment			
Nil	48	4.0	0.6
Aureomycin + B_{12}	48	5.9	
Antibiotic-processing interactions			
Linseed oilmeal + nil	6	5.8	
+ aureomycin	6	8.9	
Rapeseed oilmeal + nil	6	4.7	
+ aureomycin	6	3.9	
R.S.O.M. 10–5* + nil	6	3.9	
+ aureomycin	6	5.3	
R.S.O.M. 10–10 + nil	6	3.4	
+ aureomycin	6	4.5	
R.S.O.M. 10–15 + nil	6	3.0	
+ aureomycin	6	5.8	
R.S.O.M. 20–5 + nil	6	3.6	
+ aureomycin	6	6.6	
R.S.O.M. 20–10 + nil	6	4.3	
+ aureomycin	6	6.4	
R.S.O.M. + nil	6	3.5	
+ aureomycin	6	6.0	

* Rapeseed oilmeal steamed 10 min. @ 5 lb. pressure.

Iodinated casein at the 0.5 per cent level caused rather high mortality and very low gains in the survivors. The simultaneous use of Aurofac reduced the death losses and permitted some mice to gain somewhat more weight, particularly in the case of those diets involving the more drastic steam treatments. The results suggest that aureomycin rendered the animals slightly more tolerant to iodinated casein.

The conclusions drawn from this study were that steam treatments of up to 20 minutes at 15 lb. pressure, iodine, iodinated casein and/or aureomycin failed to offset the rapeseed oilmeal factor satisfactorily. The trends toward improvement due to high-levels of Aurofac and to iodine seem worthy of further investigation.

Experiment No. 2—(Steam and extraction treatments)

Analysis of the weight gains in this experiment revealed that the general effects of extracting rapeseed oilmeal with water, with or without prior steaming, were beneficial. The improvement was not sufficient to

render rapeseed oilmeal equal to the control supplement of soybean oilmeal + fishmeal. Likewise the general responses to supplemental antibiotics and to vitamin B_{12} were favourable but, as in previous work (3), the added iodine was deleterious to growth. Since significant first order interactions existed between vitamin B_{12}, antibiotics and types of protein supplements these effects are presented in Table 2. From these data it appears that water extraction, steam cooking and steaming followed by extraction each affected some, and about equal, improvement in rapeseed oilmeal. The feeding of extracted rapeseed oilmeal with the extract returned showed no effect on its quality. The steam cooking of the extract prior to re-incorporation into the meal was also ineffective, which suggests that the effect of the steam cooking was on some fraction that remained in the residue after water extraction. Unfortunately, accurate feed intake records were not available to permit a study of the treatments in the light of possible differences in feed consumption. Nevertheless, the possibility exists that more than one deleterious factor occurs in rapeseed oilmeal in view of the apparently separate effects of water extraction and steam cooking.

The re-incorporation of the neutralized, hydrolyzed extract into the residue resulted in a pronounced deleterious effect. The reason for this is not apparent from the observations made, but the possibility that a toxic factor was released during hydrolysis from a complex of low original biological availability should be explored further.

It is shown in Table 2 that vitamin B_{12} was not consistently effective in improving rates of gain. Its use with rapeseed oilmeal improved gains by as much as either water extraction or steam cooking but a combination of vitamin B_{12} and water extraction was superior to either treatment alone. The gains obtained were significantly lower than for the control soy-fish ration; nevertheless the effect would seem to be of practical importance. It cannot be concluded definitely that the vitamin was acting specifically against the toxic factor.

The effects of the antibiotic mixture were generally favourable with the rapeseed oilmeal rations but statistical significance was attained only with untreated rapeseed oilmeal, steamed rapeseed oilmeal and with extracted rapeseed oilmeal to which the steam-cooked extract had been added. It cannot, therefore, be decided whether or not the antibiotics exercised any specific effect against the rapeseed oilmeal growth depressant.

A significant interaction existed between antibiotics and vitamin B_{12}. This effect bears no particular relationship to the rapeseed oilmeal problem but it is of nutritional interest. The antibiotic response was favourable in both the absence and the presence of added vitamin B_{12}; but whereas vitamin B_{12} stimulated growth in the absence of antibiotics, it did not do so in the presense of antibiotics. This would suggest that at least part of the antibiotic response may be due to sparing effects on dietary vitamin B_{12} requirements, about which several reports have appeared.

The possibility of the existence of more involved interrelationships between the various treatments has been studied. Table 2 contains all the comparisons which proved to contain significant differences. It can, therefore, be stated that the results presented and discussed above were not altered by other experimental treatments.

TABLE 2.—EFFECTS OF VARIOUS TREATMENTS OF RAPESEED OILMEAL AND SUBSEQUENT RATION SUPPLEMENTS ON GROWTH RATES OF MICE. (Experiment 2)

Treatment	No. of mice	Average gain	Necessary difference
		gm.	gm.
Vitamin B_{12} effects			
Soybean oilmeal + fishmeal + nil	12	11.9	
+ B_{12}	12	11.9	
Rapeseed oilmeal + nil	12	5.1	
+ B_{12}	12	7.9	
Steamed R.S.O.M. + nil	12	6.8	
+ B_{12}	12	7.3	
Water extracted R.S.O.M. + nil	12	7.6	
+ B_{12}	12	9.0	1.4
Steamed, extracted R.S.O.M. + nil	12	6.8	
+ B_{12}	12	9.4	
Extracted R.S.O.M. + extract + nil	12	5.9	
+ B_{12}	12	4.1	
Extracted R.S.O.M. + steamed extracted + nil	12	4.1	
+ B_{12}	12	6.2	
Extracted R.S.O.M. + hydr. extracted + nil	12	1.7	
+ B_{12}	12	1.7	
Antibiotic effects			
Soybean oilmeal + fishmeal + nil	12	11.7	
+ antibiotic	12	12.1	
Rapeseed oilmeal + nil	12	5.4	
+ antibiotic	12	7.5	
Steamed R.S.O.M. + nil	12	5.2	
+ antibiotic	12	8.9	
Extracted R.S.O.M. + nil	12	7.8	
+ antibiotic	12	8.8	1.4
Steamed extracted R.S.O.M. + nil	12	7.6	
+ antibiotic	12	8.7	
Extracted R.S.O.M. + extract + nil	12	4.4	
+ antibiotic	12	5.5	
Extracted R.S.O.M. + steamed extract			
+ nil	12	4.2	
+ antibiotic	12	6.1	
Extracted R.S.O.M. + hydr. extract + nil	12	1.4	
+ antibiotic	12	2.0	
Vitamin B_{12} x antibiotic interaction effects			
No B_{12}, no antibiotic	48	5.2	
" " + "	48	7.3	0.7
B_{12} no "	48	6.7	
" + "	48	7.6	
Iodine effects			
No iodine	96	7.1	0.5
Iodine	96	6.3	

The findings of most interest in regard to counteraction of the growth depressor may be summarized thus: (a) water extraction and steam cooking effected some improvement; (b) vitamin B_{12} as a dietary supplement was as effective as water extraction or steam cooking; (c) vitamin B_{12} and water extraction had additive effects; (d) antibiotics *per se* were of little, if any, value except as far as they may have facilitated the synthesis or utilization of vitamin B_{12}; (e) supplemental iodide had adverse effects on the rapeseed oilmeal diets, and (f) the behaviour of the mice fed water-extracted, steamed and hydrolyzed extracts again suggests the existence of more than one deleterious factor.

The results of the *post-mortem* gross examinations of the thyroid glands were less readily evaluated than were the gains because of the nature of the rating system. The experimental history of the mouse was not known, however, by the technician at the time of examination. The most notable observation was that those mice which received supplemental iodine had an average rating of 3.2 as compared to 1.5 for those receiving no iodine and thus had experienced thyroid distress. By contrast, the average rating for both the antibiotic treated and the control mice was 2.3 and for the B_{12} and the B_{12}-free mice the ratings were 2.2 and 2.4 respectively. This evidence indicates that neither vitamin B_{12} nor antibiotics were of direct value in counteracting the goitrogen in rapeseed oilmeal and that iodine was not beneficial.

The thyroid examinations gave no indication of marked superiority of any process applied to rapeseed oilmeal, In fact, normal or nearly normal glands by reason of apparent size, colour and general outward appearance were found on the untreated rapeseed oilmeal diets. This is in contrast with other observations on other species (4, 6). In view of the adverse effects of iodinated casein, it would appear that the possibility of direct interference with tissue oxidations should be explored.

Experiment No. 3—(Water and alcohol extractions, steam sterilization)

Analysis of the initial weights in this experiment indicated some differences between certain treatments at the time of allotment. Also a

TABLE 3.—THE EFFECTS OF VARIOUS EXTRACTIONS, STERILIZATION PROCESSES AND OF IODINE SUPPLEMENTATION ON FEED INTAKES AND GROWTH OF MICE (Experiment 3)

Treatments	No. of mice	Feed intake*	Adjusted average gain	Nec. diff. (P = .05) for gains
		gm.	gm.	gm.
Untreated rapeseed oilmeal	10	39	7.9	
H_2O extracted R.S.O.M.	10	35	7.0	
H_2O extracted R.S.O.M. + germ. seeds	10	38	7.8	
Alcohol extracted R.S.O.M.	10	34	6.8	1.1
Complete diet sterile, R.S.O.M.	10	35	6.9	
Basal diet sterile, R.S.O.M.	10	41	8.6	
Soybean oilmeal control	10	44	9.3	
No iodine	35	38	7.6	0.6
0.003% iodine	35	39	7.9	

* Necessary difference (P = 0.05) for feed intakes is 5 gm. for processing effects and 2 gm. for iodine effects.

highly significant correlation (r = 0.759, 55 D.F.) was found between feed intakes and observed gains. Hence the data were subjected to multiple correlation analysis of initial weights, feed consumption and gains.

In Table 3 it is obvious that none of the treatments imposed on rapeseed oilmeal effected significant improvement over the untreated meal. In fact, the alcohol extraction reduced both the observed feed intake and the gains (observed and adjusted).

It can be concluded that enzymes present in the rapeseed oilmeal or in the other dietary ingredients probably have no effect on the behaviour of the growth inhibitor in rapeseed oilmeal. Despite the fact that water extraction in the presence of germinating seeds facilitated the removal of thiooxazolidone (8), this procedure effected no improvement in the residue as a feedstuff.

The failure of water extraction alone to be effective opposes the findings in *Experiment No. 2* and in earlier work (1). The reasons cannot be ascertained but it will be noted that gains obtained in mice fed the water-extracted meals were similar in the two tests, whereas the gains from the untreated rapeseed oilmeal in *Experiment No. 2* were lower than in this test. There were differences in the basal diets and possibly in the rapeseed oilmeal, since the proportions of Polish-type rape in commercial products had increased in the interval.

The response to 0.003 per cent iodine was insignificant except for the rations that underwent complete sterilization and the soybean oilmeal ration. In the former instance the favourable response to iodine constituted an improved gain only when compared to the significantly depressed growth rate obtained from the completely sterilized, iodine-free ration.

The effect of iodine approached significance (at P = 0.05) for the rapeseed oilmeal rations having the basal portions sterilized and was significant for the soybean ration which also had the basal portion sterilized. Thus the effect of iodine concerned the basal components of the diets and not the rapeseed oilmeal fractions.

TABLE 4.—EFFECTS OF ACID HYDROLYSIS, ALCOHOL EXTRACTION AND WATER EXTRACTION OF RAPESEED MEAL; OF ALLYLISOTHIOCYANATE AND CERTAIN MINERALS ON GROWTH AND FEED CONSUMPTION OF MICE (Experiment 4)

Ration supplement	No. of mice	Feed intake	Observed gain	Adjusted gain
		gm.	gm.	gm.
Rapeseed oilmeal (R.S.O.M.)	20	38	5.0	5.9
Acid hydrolyzed R.S.O.M.	20	36	4.8	6.1
Hot-alcohol extracted R.S.O.M.	20	43	9.0	9.2
Hot-water extracted R.S.O.M.	20	43	8.2	8.4
Soybean oilmeal + meat meal	20	29	12.4	11.7
Soybean oilmeal + meat meal + allylisothiocyanate	20	55	12.0	10.3
Necessary difference (P = .05)		*4*	*1.4*	*1.3*
Nil	24	41	8.7	9.1
$CuSO_4$, 0.075%	24	44	8.6	8.6
3-nitro phenylarsonic acid, 0.02%	24	46	9.1	8.9
$AgNO_3$, 0.02%	24	43	8.0	8.1
NaF, 0.02%	24	44	8.3	8.1
Necessary difference (P = .05)		*4*	*1.3*	*1.2*

Experiment No. 4 (Acid hydrolysis, hot water and hot alcohol extractions)

The variance analyses of the data revealed significant effects of processing methods and of supplements on both feed intakes and gains. The gains were ultimately adjusted for feed intake differences because the correlation between the two was highly significant, r being 0.424 (r at $P = 0.01$ is 0.283).

Table 4 shows that feed consumption of the mice fed the alcohol- or water-extracted meals was greater than that of those fed the untreated meal. These differences were associated with higher observed gains as well as adjusted gains, which means that differences in feed intakes *per se* did not account for the gain differences. Despite the improvement in gains, the extraction procedures did not improve the rapeseed oilmeal sufficiently to equal the control ration of soybean oilmeal and meat meal. It seems doubtful that vitamin or amino acid deficiencies were involved considering the high level of rapeseed oilmeal used and the presence of alfalfa meal and brewers' yeast.

The general effects of the various mineral treatments were negligible, as seen in Table 4. The interaction data are shown in Table 5 and while none of the treatments was beneficial to untreated rapeseed oilmeal rations, some effects are evident among the processed meals. $AgNO_3$ significantly depressed gains in the presence of allyl isothiocyanate but not elsewhere.

The addition of allyl isothiocyanate to the soybean-meal ration resulted in a significant increase in feed consumption but without a corresponding change in rate of gain. On a comparable feed intake basis the adjusted gains were lower which indicates that the compound did exert an unfavourable effect on feed efficiency. As noted previously, however, the level employed here may have been too low, in view of more recent analytical data, to evaluate it properly in relation to the rapeseed oilmeal toxicity problem.

TABLE 5.—EFFECTS OF $CuSO_4$, 3-NITRO PHENYLARSONIC ACID, $AgNO_3$ AND NaF ON THE GROWTH RESPONSES IN MICE FED RAPESEED OILMEAL RATIONS. GAINS ADJUSTED FOR DIFFERENCES IN FEED INTAKES (EXPERIMENT 4)

Ration	Treatment				
	Nil	$CuSO_4$	3-nitro	$AgNO_3$	NaF
	gm.	gm.	gm.	gm.	gm.
Rapeseed oilmeal (R.S.O.M.)	6.5*	5.6	5.6	6.7	5.0
Acid hydrolyzed R.S.O.M.	6.9	5.6	6.0	4.8	7.0
Alcohol extracted R.S.O.M.	8.7	9.1	10.6	8.9	8.6
Water extracted R.S.O.M.	9.7	7.5	8.6	8.5	7.3
Soybean oilmeal + meat meal	10.8	12.7	12.1	11.3	11.2
Soybean oilmeal + meat meal + allylisothiocyanate	12.1	11.1	10.1	8.3	9.6

* Necessary difference between any pair ($P = 0.05$) is 2.9 gm.

In summarizing this experiment, it may be stated that hot alcohol and hot water extractions of rapeseed oilmeal significantly improved its feeding value but that attempts to employ heavy metals or other materials that might delay or inhibit the release of the goitrogen from its glucoside complex (7) were unsuccessful.

This series of experiments failed to provide a method for adequately counteracting the deleterious effect of rapeseed oilmeal when fed as a major ingredient in rations. Steam cooking as long as 20 minutes at 15 lb. pressure produced no beneficial effects but some improvement was made by processing for 30 minutes at 20 lb. pressure. The effect obtained was comparable in magnitude to that produced by water extraction (25°C.). It was found, however, that pressure cooking of the aqueous extract did not reduce its toxicity; hence it is possible that water extraction and steam processing of the oilmeal affected different factors.

The significance of the finding that hot acid hydrolysis of the water extract increased its toxicity is not clear, especially in view of the failure of 1 per cent hydrochloric acid (40°C.) to modify the nutritive value of the oilmeal.

Treatments having little or no effect in these studies were: steam processes less severe than 20 minutes at 15 lb. pressure; dietary iodide; iodinated casein; antibiotics; vitamin B_{12}; $CuSO_4$, 3-nitrophenylarsonic acid, $AgNO_3$, and NaF. Procedures particularly worthy of further investigation are hot ethyl alchohol extraction, hot water extraction, and acid hydrolysis.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the assistance of Elinor Baker and Greta McKay in certain phases of these experiments.

Financial assistance was provided by the National Research Council of Canada, through the Associate Committee on Animal Nutrition.

REFERENCES

1. Bell, J. M., and K. Williams. Growth depressing factors in rapeseed oilmeal. Can. J. Agr. Sci. 33 : 201-209 1953.
2. Bell, J. M. The nutritional value of rapeseed oilmeal : A review. Can. J. Agr. Sci. 25 : 242-251 1955.
3. Bell, J. M., and E. Baker. Growth depressing factors in rapeseed oilmeal. II. Studies on counteraction by dietary supplements. Can. J. Animal Sci. 37 : 21-30. 1957.
4. Blakely, R. M., and R. W. Anderson. Studies with rapeseed oilcake meal. II. The effect of the inclusion of protamone in the diet, on the thyroid enlargement induced by the feeding of rapeseed oilcake meal to turkey poults. Sci. Agr. 28 : 398-402. 1948.
5. Dow, D. S., and C. E. Allen. Rapeseed oilmeal in broiler rations with observations on the nature and control of its metabolic inhibitors. Can. J. Agr. Sci. 34 : 607-613. 1954.
6. Kennedy, T. H., and H. D. Purves. Studies on experimental goitre. I. The effect of *Brassica* seed diets on rats. Brit. J. Exptl. Pathol. 22 : 241-244. 1941.
7. Matet, J., R. Montagne, and A. Bucky. Nutritive value of rapeseed oilmeal. Oleagineux 4 : 145-154. 1949.
8. Raciszewski, Z. M., E. Y. Spencer, and L. W. Trevoy. Chemical studies of a goitrogenic factor in rapeseed oilmeal. Can. J. Technol. 33 : 129-133. 1955.
9. Viehoever, A., J. F. Clevenger, and C. O. Ewing. Studies in mustard seeds and substitutes. 1. Chinese colza. J. Agr. Research 20 : 117-140. 1920.

GROWTH DEPRESSING FACTORS IN RAPESEED OILMEAL.

IV. COMPARATIVE FEEDING VALUES OF ARGENTINE AND POLISH TYPES AND THE EFFECTS OF SUPPLEMENTARY AUREOMYCIN, FISHMEAL, LYSINE, IODIDE AND THYROID-ACTIVE SUBSTANCES

J. M. Bell

University of Saskatchewan, Saskatoon, Sask.

[Received for publication August 1, 1956]

ABSTRACT

Two experiments were carried out to compare the feeding values of oilmeals derived from Argentine and Polish types of rape. In the first, four rapeseed oilmeal samples were used: (1) new oilmeal representing a commercial mixture of approximately equal parts of both types; (2) old oilmeal, predominantly of Argentine type and which had been stored five years at room temperature in a porous container; (3) Argentine type, and (4) Polish type. According to a factorial design, each oilmeal was tested as either the entire protein supplement, in a 25 per cent protein ration, or as half the supplement along with either linseed oilmeal or skimmilk powder. As cross treatments with each of these 12 rations the following were tested: (1) nil; (2) 0.01 per cent iodinated casein; (3) 20 p.p.m. aureomycin, and (4) iodinated casein plus aureomycin.

In the second experiment, three 'goitrogenic' basal diets were used: (1) soybean oilmeal and linseed oilmeal with 0.15 per cent dl-5-vinyl-2-thiooxazolidone; (2) Argentine rapeseed oilmeal, and (3) Polish rapeseed oilmeal. Three subtreatments were superimposed on each of these: (1) nil; (2) 5 per cent fishmeal, and (3) 0.5 per cent dl-lysine. Cross-treatments of (1) nil, (2) 0.02 per cent iodinated casein, (3) 0.0002 per cent sodium l-thyroxine, and (4) 0.014 per cent iodine as KI-calcium stearate were also investigated.

The tests involved 252 male mice with records on their gains and individual feed intakes.

No marked differences were found between kinds of rapeseed oilmeal. The Argentine and Polish types had 0.4 and 0.3 per cent allyl isothiocyanate equivalent, respectively. Neither linseed oilmeal, skimmilk powder, fishmeal nor lysine proved beneficial at the levels of rapeseed oilmeal tested, but the latter two modified the response to thyroid supplements.

Iodinated casein, thyroxine and iodide were likewise ineffective against the growth-depressing factor in rapeseed oilmeal. These findings are discussed in relation to apparently opposing results from other investigators.

INTRODUCTION

A report by Wetter and McConnell[2] indicated a wide range of goitrogen levels in different types of rapeseed oilmeals, with values from 0.3 to 1.4 per cent expressed as allyl isothiocyanate. While these values may not include the total goitrogenic or growth-depressant material, they may provide a partial explanation of the controversy in published findings on the toxicity of rapeseed oilmeal.

In tests designed to compare several different samples of oilmeal it seemed advisable to obtain further information on materials such as iodinated casein, iodine and antibiotics which have so far proven to be ineffective for counteracting growth depression in mice fed rapeseed oilmeal (2, 3). The finding of Kratzer *et al.* (5), that lysine was beneficial in chick diets containing rapeseed oilmeal, was also investigated. This is of special interest because Dow and Allen (4) ascribed the value of fishmeal, in diets containing rapeseed oilmeal, to its iodine content rather than to amino acids.

[1] Professor and Head, Department of Animal Husbandry, University of Saskatchewan, Saskatoon, Sask.
[2] Wetter, L. R., and W. McConnell. *Private communication.* 1955.

MATERIALS AND METHODS

Experiment No. 1

The objectives of this study were to compare four types of rapeseed oilmeal with regard to their growth-inhibiting properties and the response of mice to these oilmeals when fortified with supplements of other proteins, iodinated casein and an antibiotic.

The samples of rapeseed oilmeal were: (a) new rapeseed oilmeal containing about equal parts of Argentine and Polish types rapeseed oilmeal; (b) old rapeseed oilmeal, of mainly Argentine type and that had been stored for five years at room temperature; (c) Argentine rapeseed oilmeal, and (d) Polish rapeseed oilmeal. The last two samples were prepared commercially just prior to the feeding test.

These oilmeals were tested in a $3\times4\times4$ factorial experiment as either the entire source of supplemental protein in 25 per cent protein rations, or as half the added protein along with linseed oilmeal or with skimmilk powder. In this manner the oilmeals were tested at high levels (50 per cent) of intake, and at low (25 per cent) levels, in conjunction with either plant or animal origin protein feeds.

Four cross-treatments were applied to each of the protein combinations mentioned above. These were: (1) nil, in order to study the protein treatments *per se*; (2) 0.01 per cent iodinated casein (Protamone[1]) in view of the possibility that the ill effects previously found (2, 3) might have been related to the type of rape involved; (3) 20 p.p.m. aureomycin[2], and (4) iodinated casein and aureomycin combined.

The basal ration employed was composed of barley 40, wheat 40, brewers' dried yeast 4, alfalfa meal 10, and minerals (2) 6 per cent. Vitamins A, D and E were added to satisfy known requirements. The protein supplements were mixed in equal parts with the basal ration and the appropriate iodinated casein and aureomycin supplements were then added to the allotted portions for each diet.

Three male mice were randomly allotted to each diet and individual feed records were kept. Management details have been described elsewhere (2).

Experiment No. 2

This study was conducted in order to compare Argentine and Polish rapeseed oilmeals with a non-rapeseed diet containing the goitrogen thiooxazolidone. The experiment involved three main rations: (a) an equal-parts mixture of soybean oilmeal and linseed oilmeal with dl-5-vinyl-2-thiooxazolidone added to supply a level of 0.15 per cent in the diets; (b) one containing Argentine rapeseed oilmeal, and (c) one with Polish rapeseed oilmeal, all providing 25 per cent protein in the final mixtures as fed.

Each of the three rations was tested with three different sub-treatments: (1) nil; (2) fishmeal as 5 per cent of the diet, and (3) dl-lysine as 0.5 per cent of the diet and designed to approximate the l-lysine contribution of the fishmeal.

[1] Courtesy, Cerophyll Laboratories Inc., Kansas City, Mo.
[2] Courtesy, Lederle Laboratories Division, Pearl River, N.Y.

Four cross-treatments were imposed on each of the above nine rations in order to evaluate certain thyroid-active materials. These were (1) nil; (2) 0.02 per cent iodinated casein; (3) 0.0002 per cent 1-thyroxine[1], and (4) 0.014 per cent iodine as KI-calcium stearate.

The basal diet formula was barley 40, wheat 40, brewers' dried yeast 4, vitagrass 10, minerals[2] 6 per cent, with added vitamins A and D.

RESULTS AND DISCUSSION

Experiment No. 1

Variance analysis of the feed consumption data indicated that no significant treatment effects existed but there was a highly significant correlation ($r=0.69$, 95D.F.) between feed intake and gains. Only the adjusted gains, therefore, are shown in Table I. It is possible that the lack of significant differences in feed intakes on different diets may have been due to an unusually great variability of mouse responses in this test. The coefficients of variability were 40 and 25 per cent respectively for feed intakes and observed gains. The reasons for the large variations are not evident but this situation does not invalidate the other observations.

No differences were found between the various types of rapeseed oilmeal. Recent analyses[3], however, showed that the goitrogen contents of the Argentine and the Polish oilmeals were 0.4 and 0.3 per cent, respectively. These values represent the equivalent of allyl isothiocyanate and may not truly indicate the growth-depressing properties of the samples tested. These analyses and the growth tests suggest that the oilmeals used were rather similar in goitrogen content.

[1] Courtesy, Glaxo Laboratories Ltd., Greenford, Middlesex, England. (Described as a 1 per cent triturate of synthetic sodium L-thyroxine in an inert base).
[2] Bone meal 280, $CaCO_3$ 470, $FeSO_4.7H_2O$ 20, $MgSO_4.7H_2O$ 20, $MnSO_4.4H_2O$ 0.5 and NaCl 280 gm.
[3] Wetter, L. R., and W. McConnell. *Private communication.* 1955.

TABLE 1.—EFFECTS ON RATES OF GAIN IN MICE OF SUPPLEMENTAL IODINATED CASEIN, AUREOMYCIN, LINSEED OILMEAL AND MILK POWDER IN RATIONS CONTAINING VARIOUS KINDS OF RAPESEED OILMEAL

Protein supplements	Supplements			
	Nil	Iodinated casein	Aureomycin	Iod. casein + aureo.
	(Gains in grams)			
New rapeseed oilmeal				
+ nil	10.1	10.1	8.0	7.8
+ linseed oilmeal	10.7	8.5	6.9	6.3
+ milk powder	10.2	8.6	7.3	11.2
Old rapeseed oilmeal				
+ nil	8.0	8.5	8.2	10.8
+ linseed oilmeal	9.5	9.1	10.3	6.9
+ milk powder	11.0	7.4	7.7	11.1
Argentine rapeseed oilmeal				
+ nil	9.0	9.5	9.1	9.0
+ linseed oilmeal	9.3	8.3	8.2	9.4
+ milk powder	9.2	11.5	9.8	12.2
Polish rapeseed oilmeal				
+ nil	10.3	8.6	7.0	9.2
+ linseed oilmeal	9.1	8.6	8.6	8.5
+ milk powder	9.5	8.4	10.9	9.8

Necessary difference at $P = 0.05$ is 2.8 gm.

The general effect of skimmilk powder as a partial substitute for rapeseed oilmeal was favourable but there was an interaction involving types of rapeseed oilmeal as well as the iodinated casein and aureomycin treatments. These interaction effects are shown in Table I.

The data indicate that the substitution of linseed oilmeal was of no value with any type of rapeseed oilmeal or with any other supplement used. The same probably can be said for skimmilk powder, since it was effective only with old rapeseed oilmeal without iodinated casein or aureomycin. Thus the use of linseed oilmeal and skimmilk powder was of no benefit in rations containing 25 per cent rapeseed oilmeal.

The inclusion of antibiotics and iodinated casein, singly or together, was generally ineffective; but it is noted that a combination of the two along with skimmilk powder produced nearly normal gains in mice fed Argentine rapeseed oilmeal.

Experiment No. 2

Analyses of the growth and feed consumption data indicated that mice fed thiooxazolidone-supplemented diets gained more slowly and consumed less feed than did mice fed rapeseed oil meal diets. A highly significant correlation was found between feed intakes and gains ($r = 0.79$; 71 D.F.). Differences between adjusted gains suggested that the effects of thiooxazolidone probably were related to appetite or palatability rather than to feed utilization. In fact, with feed intakes statistically equalized, the mice fed thiooxazolidone grew more rapidly than did those fed Polish rapeseed oilmeal.

As in the previous experiment, there appeared to be no marked differences due to kinds of rapeseed oilmeal (Table 2). As far as the thiooxazolidone diets were concerned, the superior responses may have been due to the soybean and linseed oilmeals providing a better supplement than rapeseed oilmeals rather than to any stimulatory effect of the added goitrogen. As mentioned earlier, there is reason to believe that the level of thiooxazolidone was too low to provide a good comparison with rapeseed oilmeal. It seems reasonable to conclude that mice cannot make normal gains when fed diets containing 0.15 per cent dl-thiooxazolidone, since in previous studies gains of about 12 gm. were typical of mice fed good rations.

With regard to the attempts to influence thyroid activity, it was found that 0.02 per cent iodinated casein (Table 3) had no general effect on either feed consumption or gains. Thyroxine (0.0002 per cent) reduced gains and showed no tendency, as iodinated casein has in some experiments, to increase feed intakes. The inclusion of KI resulted in lower adjusted gains compared to the controls. As shown in Table 2, the responses to the various thyroid treatments were similar for all three basal diets. In no instance were 'normal' gains obtained.

The similarity of responses between the thiooxazolidone and the rapeseed oilmeal diets leads to the conclusion that neither the pure synthetic goitrogen nor the natural material in rapeseed oilmeal can be counteracted by iodinated casein, thyroxine or iodide in the diet of the mouse.

The inclusion of 5 per cent fishmeal or of 0.5 per cent l-lysine (Table 3) produced no general effects on either feed intakes or gains and this was

TABLE 2.—COMPARISON OF ARGENTINE AND POLISH TYPES OF RAPESEED OILMEAL WITH THIOOXAZOLIDONE-TREATED DIETS, SUPPLEMENTED WITH THYROID-ACTIVE MATERIALS, FISHMEAL AND LYSINE. FEED INTAKES AND WEIGHT GAINS IN MICE

Treatment	No. of mice	Feed intake	Gain	Adjusted gain
		(gm.)	(gm.)	(gm.)
Basal rations				
0.15% dl-thiooxazolidone	36	31.6	6.0	7.6
50% Argentine rapeseed oilmeal	36	36.6	7.2	6.9
50% Polish rapeseed oilmeal	36	38.8	7.5	6.3
Nec. difference (P=0.05)		2.7	1.3	0.8
Basal ration × thyroid treatments				
Thiooxazolidone				
+ nil	9	29.2	6.3	8.8
+ iod. casein	9	35.0	8.2	8.5
+ thyroxine	9	31.5	4.6	6.2
+ KI	9	30.6	4.9	6.9
Argentine rapeseed oilmeal				
+ nil	9	38.2	7.9	6.9
+ iod. casein	9	33.2	7.1	8.1
+ thyroxine	9	37.9	6.3	5.4
+ KI	9	37.0	7.6	7.1
Polish rapeseed oilmeal				
+ nil	9	39.1	9.2	7.9
+ iod. casein	9	41.1	8.3	6.1
+ thyroxine	9	37.4	5.1	4.4
+ KI	9	37.5	7.3	6.6
Nec. difference (P=0.05)		5.4	2.6	1.6
Basal ration × protein treatments				
Thiooxazolidone				
+ nil	12	31.5	5.6	7.2
+ fishmeal	12	28.8	5.5	8.2
+ lysine	12	34.4	6.8	7.3
Argentine rapeseed oilmeal				
+ nil	12	35.2	6.4	6.6
+ fishmeal	12	38.2	8.1	7.1
+ lysine	12	36.3	7.1	6.8
Polish rapeseed oilmeal				
+ nil	12	39.5	7.4	5.0
+ fishmeal	12	37.6	7.7	7.0
+ lysine	12	39.3	7.3	5.9
Nec. difference (P=0.05)		4.7	2.3	1.4

true regardless of the type of basal diet used (Table 2). These results with mice differ from those reported by Kratzer *et al.* (5) and Dow and Allen (4) who found supplemental lysine and iodide to be beneficial with chickens. The possibility of inherent species differences remains and it should be noted that the effects of fishmeal approached significance at P = .05. Since the coefficient of variability was quite large in this experiment (24 per cent) the difference required for statistical significance was

TABLE 3.—EFFECTS OF THYROID-ACTIVE SUPPLEMENTS, FISHMEAL AND LYSINE ON GAINS AND FEED CONSUMPTION OF MICE FED 'GOITROGENIC' RATIONS

Treatment	No. of mice	Feed intake	Gain	Adjusted gain
		(gm.)	(gm.)	(gm.)
Thyroid treatments				
Nil	27	35.4	7.8	7.9
Iodinated casein	27	36.5	7.9	7.6
l-thyroxine	27	35.6	5.3	5.3
KI-Ca stearate	27	35.0	6.6	6.9
Nec. difference (P = 0.05)		3.1	1.5	0.9
Protein and amino acid treatments				
Nil	36	35.3	6.5	6.7
Fishmeal	36	34.9	7.1	7.5
Lysine	36	36.7	7.1	6.7
Nec. difference (P = 0.05)		2.7	1.3	0.8
Thyroid × protein interaction effects				
Nil + nil	9	34.4	7.1	7.6
+ fishmeal	9	34.6	8.4	8.8
+ lysine	9	38.6	7.9	6.8
Iod. casein + nil	9	38.8	6.8	5.6
+ fishmeal	9	34.3	8.1	8.6
+ lysine	9	37.2	8.7	8.1
Thyroxine + nil	9	34.0	5.8	6.5
+ fishmeal	9	35.6	4.8	4.8
+ lysine	9	37.3	5.3	4.7
KI + nil	9	35.4	6.3	6.4
+ fishmeal	9	35.0	7.1	7.4
+ lysine	9	34.7	6.4	6.8
Nec. difference (P = 0.05)		5.4	2.6	1.6

greater than usual. Despite the possibility that fishmeal may be beneficial it seems doubtful that it would completely counteract the rapeseed effect because the gains obtained were far from normal.

The interaction between thyroid treatments and the fishmeal-lysine treatments is of some interest (Table 3). When no thyroid treatment was involved the fishmeal-fed mice grew better than the lysine-fed ones regardless of type of basal diet. It is possible that fishmeal improved the quality of the protein in the rations through some amino acid other than lysine. In view of the possibility that phenylalanine could be deficient (1), a further study of amino acids may be warranted.

In the presence of iodinated casein the adjusted gains were greater when either fishmeal or lysine were added than when neither supplement was added. The improvement in growth appears to be a result of improved food utilization. When thyroxine was fed, the inclusion of either fishmeal or lysine depressed gains compared to the controls. On the other hand,

KI effects were not influenced by fishmeal or lysine. Thus with three distinctly different responses to the three iodine sources, in relation to fishmeal and dl-lysine supplements, these effects may have some bearing on the reported efficacy of iodine and lysine as adjuncts to diets containing rapeseed oilmeal.

These two experiments have indicated no differences in feeding value between Argentine and Polish rapeseed oilmeal samples that proved to have 0.4 and 0.3 per cent of allyl isothiocyanate respectively. Goitrogen contents, however, appear to vary widely both between and within rape strains and varieties and possibly in relation to environmental factors. As in previous studies in this laboratory, growth-inhibiting effects were evident and the inclusion or substitution of other types of protein supplements, or of dl-lysine, failed to demonstrate any specific need for additional amino acids. In accord also with earlier reports, thyroid-active materials failed to counteract the growth-inhibiting factor(s) in rapeseed oilmeal.

ACKNOWLEDGEMENTS

The author acknowledges the financial assistance provided by the National Research Council of Canada through the Associate Committee on Animal Nutrition, and the assistance of Barbara D. W. Welch and James Erfle.

REFERENCES

1. Bell, J. M. The nutritional value of rapeseed oilmeal: A review. Can. J. Agr. Sci. 35 : 242-251. 1955.
2. Bell, J. M., and E. Baker. Growth depressing factors in rapeseed oilmeal. II. Studies on counteraction by dietary supplements. Can. J. Animal Sci. 37 : 21-30. 1957.
3. Bell, J. M. Growth depressing factors in rapeseed oilmeal. III. Studies on counteraction by steam processing, extraction and dietary supplements. Can. J. Animal Sci. 37 : 31-42. 1957.
4. Dow, D. S., and C. E. Allen. Rapeseed oilmeal in broiler rations with observations on the nature and control of its metabolic inhibitors. Can. J. Agr. Sci. 34 : 607-613. 1954.
5. Kratzer, F. H., P. N. Davis, D. E. Williams, and B. J. Marshall. Factors influencing the growth of chicks and poults fed rations containing rapeseed oilmeal. J. Nutrition 53 : 407-418. 1954.

THE EFFECT OF CONCENTRATE TO HAY RATIO AND OTHER RATION FACTORS ON THE FEEDLOT PERFORMANCE OF BEEF CATTLE[1]

FRANK WHITING

Canada Department of Agriculture, Lethbridge, Alberta

[Received for publication December 10, 1956]

ABSTRACT

Two experiments were carried out with Hereford and Aberdeen Angus steer calves to study the influence of feeding concentrate and hay in the ratios of 1:2, 1:1, 2:1; of feeding the concentrate in the pelleted and the ground form; of pelleting the entire ration; and of feeding the ration *ad libitum* and according to the body weight of the animal. All comparisons were not made in each experiment. Each lot in each experiment was made up of four Aberdeen Angus and seven Hereford calves. All animals were fed individually. Only the data obtained between 500 and 900 lb. body weight were considered in this paper. The animals were slaughtered as they reached 900 lb. and certain carcass data obtained.

The steers fed concentrate to hay in the ratio of 1:2 made smaller daily gains, required more feed (T.D.N.) per unit of gain, had lower dressing percentages, and had less fat in their 9-10-11 rib sections than those fed rations with ratios of concentrate to hay of 1:1 and 2:1. The steers fed the 1:1 ratio made significantly smaller daily gains and required more feed per unit of gain than those fed the 2:1 ratio of concentrate to hay, but were not different in dressing percentage or percentage fat in the 9-10-11 rib sections.

There were no significant differences between those steers fed their concentrate in the pelleted or ground forms. In one experiment, pelleting the entire ration resulted in significantly lower daily gains than pelleting only the concentrate and feeding the hay chopped, but in the other experiment there were no differences. Pelleting the entire ration resulted in no significant differences in feed efficiency, dressing percentage, or carcass grade. Limiting the daily consumption of feed to predetermined amounts dependent upon body weight did not influence efficiency of feed utilization or carcass characteristics as compared to *ad libitum* feeding.

The Hereford steers that were fed in these two experiments made greater body gains per unit of feed consumed but had less body fat and in one experiment had lower grading carcasses than the Aberdeen Angus steers.

INTRODUCTION

Relative availability and costs of roughages and concentrates vary from year to year and from area to area in Western Canada. The feedlot operator must adjust the proportions of hay and concentrate in his rations in accordance with these costs if he is to obtain maximum returns. Only limited information is available on the influence of different ratios of concentrate to hay in the ration on the rate and economy of gain and carcass quality of beef cattle.

Keith *et al.* (7, 8) fed rations with concentrate to hay ratios varying from 4:1 to 1:3 to steer calves and yearlings. They found, in general, that average daily gains increased and total feed per unit of gain decreased as the proportion of concentrate in the ration was increased. The most economical ratios for usual feed price relationships were between 2:1 and 1:2. Pahnish *et al.* (13) fed rations with concentrate to hay ratios between 2:1 and 1:3 to yearling steers. The results were similar to those of Keith *et al.* (7, 8) in that average daily gains increased and total feed

[1] Contribution from the Division of Animal Husbandry, Experimental Farms Service.

per unit of grain decreased as the proportion of concentrate in the ration increased. Dowe *et al.* (4) fed yearling steers rations with concentrate to hay ratios between 1:1 and 5:1. The steers fed concentrate to hay in the ratio 2:1 made the most rapid gains.

Two experiments were carried out at the Experimental Farm, Lethbridge, to determine the rate and economy of gain and carcass quality of steer calves as influenced by ratios of concentrate to hay varying from 2:1 to 1:2, by pelleting the concentrate or entire ration, and by *ad libitum* and controlled feeding. Controlled feeding was used to study the variation in feed efficiency between individual animals on the same ration. This system of feeding is not considered practical in the commercial feedlot finishing of cattle, but is used by some in performance and progeny testing of cattle to provide an estimate of feed efficiency uncomplicated by differences in daily feed consumption. These experiments were conducted to obtain information both on the ratio of concentrate to hay in commercial feedlot finishing of cattle and on rations suitable for performance and progeny testing of beef cattle. The latter phase of this study will be reported elsewhere.

PROCEDURE

Experiment 1

Fifty-five steer calves (20 Aberdeen Angus and 35 Herefords) were divided at random into five lots of four Angus and seven Herefords each. The Aberdeen Angus and Hereford calves were of good quality and each breed group was from one herd. All animals were fed individually. The animals were fed as follows:

Lot 1—one part concentrate (pelleted) to two parts hay, fed according to body weight (i.e. controlled feeding).
Lot 2—two parts concentrate (pelleted) to one part hay, fed according to body weight.
Lot 3—two parts concentrate (pelleted) to one part of hay, fed *ad libitum*.
Lot 4—two parts concentrate (ground) to one part of hay, fed *ad libitum*.
Lot 5—two parts concentrate to one part of hay (complete ration pelleted) fed *ad libitum*.

Animals in Lots 1 and 2 were fed daily amounts of feed in accordance with their individual body weights. These amounts were adjusted after each weighing and were based upon what animals of similar weights in previous experiments had consumed without waste. The amounts fed (shown only at 100-lb. intervals) were as follows (air-dry weights):

Body Weight (lb.)	Lot 1 (lb.)	Lot 2 (lb.)
400	10.0	9.6
500	11.7	11.2
600	13.5	12.9
700	15.3	14.7
800	17.2	16.6
900	19.2	18.8

The hay was a mixture of two-thirds good quality alfalfa and one-third crested wheatgrass and contained 11 per cent crude protein and 35 per cent crude fibre. It was chopped coarsely to facilitate feeding. The concentrate was composed of 35 per cent barley, 35 per cent oats, 15 per cent dried molasses beet pulp, 10 per cent linseed oilmeal, and 5 per cent beet molasses. In addition, $\frac{1}{2}$ lb. each of cobaltized salt and bonemeal were added to each 100 lb. of concentrate. The concentrate mixture contained 13 per cent crude protein and 10 per cent crude fibre.

All animals were placed on their respective rations for a period of two weeks before initial weights were taken and feed intake records were started. All animals were weighed individually each Tuesday commencing at 9 a.m. They had no access to water during the 12-hour period immediately preceding weighing, but the feeding schedule was uninterrupted. Since there was considerable variation in initial weights both within and between lots, only the growth and feed data obtained between 500 and 900 lb. body weight for each animal were considered in this paper.

Each animal was slaughtered as it reached 900 lb. in body weight, regardless of apparent finish. This practice was followed to permit assessment of differences in finish at a given body weight. Data were collected on weight of hide, carcass weight, carcass grade, percentage of separable fat in the 9-10-11 rib section, and the percentage of fat (ether extract) in the "eye" muscle (*longissimus dorsi* muscle). A tracing was made on the surface cut between the 11th and 12th rib and the area of the "eye" muscle was determined with a planimeter.

Experiment 2

Fifty-five steer calves (20 Aberdeen Angus and 35 Herefords) were divided into five lots of four Aberdeen Angus and seven Herefords. The Aberdeen Angus were from one herd. Twenty-five of the Herefords were from one herd and ten from another herd. All were from different herds than those used in Experiment 1. The animals were handled and fed in the same manner as described under Experiment 1, except that they were weighed at 2-week intervals. The animals were fed as follows:

Lot 1—one part concentrate (pelleted) to two parts hay, fed *ad libitum*.
Lot 2—one part concentrate (pelleted) to one part hay, fed *ad libitum*.
Lot 3—two parts concentrate (pelleted) to one part hay, fed *ad libitum*.
Lot 4—two parts concentrate to one part hay (complete ration pelleted), fed *ad libitum*.
Lot 5—two parts concentrate to one part hay (complete ration pelleted), fed according to body weight (i.e. controlled feeding).

The animals were slaughtered as they reached 900 lb. and the same data were collected as in Experiment 1. In this experiment separable fat was determined by specific gravity, as described by Lofgreen and Garrett (9), rather than by mechanical separation.

RESULTS AND DISCUSSION

The average daily gain, efficiency of feed utilization, dressing percentage, and carcass data for steers fed from 500 to 900 lb. in body weight, as influenced by concentrate to hay ratios and by the form in which the feed was fed, are shown in Tables 1 and 2 for Experiments 1 and 2, respectively.

TABLE 1.—THE AVERAGE DAILY GAIN, FEED EFFICIENCY, DRESSING PERCENTAGE, AND CARCASS DATA FOR STEERS BETWEEN 500 AND 900 LB. WEIGHT AS INFLUENCED BY CONCENTRATE TO HAY RATIO AND BY THE FORM IN WHICH THE FEED WAS FED. (EXPERIMENT 1)

		Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
Concentrate to hay ratio		1:2	2:1	2:1	2:1	2:1
Form in which concentrate fed		pelleted	pelleted	pelleted	ground	complete ration pelleted
Form in which hay fed		chopped	chopped	chopped	chopped	*ad lib.*
Type of feeding		controlled	controlled	*ad lib.*	*ad lib.*	
Av. days on feed		255	211	197	214	193
Av. daily gain	(lb.)	1.56	1.92	2.06	1.92	2.11
Av. daily feed intake	(lb.)	14.7	14.3	15.9	15.2	16.1
Av. total feed/100 lb. gain	(lb.)	938	742	772	787	762
Av. T.D.N.[1]/100 lb. gain		532	469	489	498	484
Av. E.N.E.[1]/100 lb. gain		460	445	463	472	457
Av. cold carcass weight[2]	(lb.)	493	510	524	524	510
Av. dressing percentage[3]		54.6	56.3	57.7	57.4	56.0
Av. carcass grade[4]		Medium B	Low A	Medium A	Low A	Low A
Av. % separable fat in 9-10-11 rib		29	30	32	33	30
Av. % fat in "eye" muscle at 11th rib (D.M.B.)[5]		13	17	17	18	14
Av. depth fat over "eye" muscle at 11th rib	(mm.)	11	14	14	14	14
Av. weight kidney fat	(lb)	9	11	11	13	10
Av. area of "eye" muscle	(sq. cm.)	94	94	96	90	91

[1] Total Digestible Nutrients and Estimated Net Energy (12).
[2] After hanging in the cooler for 24 hours and with kidneys and kidney fat removed.
[3] Based upon final live weight and cold carcass weight.
[4] A—*Choice*, B—*Good* (11).
[5] Dry Matter Basis.

TABLE 2.—THE AVERAGE DAILY GAIN, FEED EFFICIENCY, DRESSING PERCENTAGE, AND CARCASS DATA FOR STEERS BETWEEN 500 AND 900 LB. BODY WEIGHT, AS INFLUENCED BY CONCENTRATE TO HAY RATIO AND BY THE FORM IN WHICH THE FEED WAS FED. (EXPERIMENT 2)

		Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
Concentrate to hay ratio		1:2	1:1	2:1	2:1	2:1
Form in which concentrate fed		pelleted	pelleted	pelleted	complete ration pelleted	complete ration pelleted
Form in which hay fed		chopped	chopped	chopped	*ad lib.*	controlled
Type of feeding		*ad lib.*	*ad lib.*	*ad lib.*		
Av. days on feed		254	220	194	218	216
Av. daily gain	(lb.)	1.60	1.84	2.06	1.86	1.85
Av. daily feed intake	(lb.)	15.3	16.2	16.5	15.0	14.4
Av. total feed/100 lb. gain	(lb.)	956	882	796	803	778
Av. T.D.N.[1]/100 lb. gain	(lb.)	546	529	509	513	498
Av. E.N.E.[1]/100 lb. gain	(lb.)	468	485	478	482	467
Av. cold carcass weight[2]	(lb.)	494	513	517	514	513
Av. dressing percentage[3]		54.6	56.8	57.5	56.6	57.1
Av. carcass grade[4]		Medium B	Low A	Low A	Medium A	Low A
Av. % separable fat, 9-10-11 rib		35	39	39	38	37
Av. % fat in "eye" muscle (D.M.B.)[5]		9	10	10	13	9
Av. depth fat over "eye" muscle	(mm.)	12	15	15	15	13
Av. weight kidney fat	(lb.)	11	14	13	11	10
Av. area of "eye" muscle	(sq. cm.)	70	77	85	84	85

[1] Total Digestible Nutrients and Estimated Net Energy (12).
[2] After hanging in the cooler for 24 hours and with kidneys and kidney fat removed.
[3] Based upon final live weight and cold carcass weight.
[4] A—*Choice*, B—*Good* (11).
[5] Dry Matter Basis.

The steers fed concentrate and hay in the ratio of 1:2 (Lot 1) made significantly ($P<0.01$) smaller daily gains and required more total feed and T.D.N. per unit of gain than those fed ratios of concentrate to hay of 2:1 (Experiments 1 and 2) or 1:1 (Experiment 2). However, when feed efficiency was based upon estimated net energy (12) per unit of gain there

were no significant ($P=0.05$) differences between these lots in either experiment. This may indicate, as has been pointed out by other workers (2, 6, 10, 12), that the T.D.N. system of comparing feed is less accurate, for productive purposes, than the estimated net energy system, especially when the feed value of a concentrate is being compared to that of a roughage. The animals in Lot 1 had significantly ($P<0.05$) lower dressing percentages, lower carcass grades, smaller areas of "eye" muscle (only in Experiment 2), and less fat in their carcasses as indicated by the amount of fat in the 9-10-11 rib sections (5) than the other lots compared above.

There were significant ($P<0.05$) differences in daily gains, feed efficiencies, and area of "eye" muscle between the lots fed concentrate and hay in the ratio of 1:1 (Lot 2, Experiment 2), and 2:1 (Lot 3, Experiment 2). However, there were no significant differences between these lots in dressing percentage, carcass grade, or the amount of fat in the carcass. Under commercial conditions, the relative cost of concentrate and roughage would be the main factor to consider in determining the most economical

TABLE 3.—THE AVERAGE DAILY GAINS AND FEED EFFICIENCIES OF STEER CALVES AS INFLUENCED BY BODY WEIGHT

Lot no.	Body weight intervals (lb.)			
	500 to 600	600 to 700	700 to 800	800 to 900
	Average daily gains (lb.)			
	Experiment 1			
1	1.32	1.51	1.67	1.62
2	1.74	1.80	2.08	2.14
3	1.90	2.06	2.14	2.20
4	1.77	1.88	2.00	2.03
5	1.86	2.13	2.20	2.26
Average	1.72	1.88	2.02	2.05
	Experiment 2			
1	1.39	1.57	1.70	1.75
2	1.65	1.92	1.77	1.85
3	1.83	2.15	2.35	1.90
4	1.71	1.95	1.93	1.85
5	1.53	1.92	2.08	1.98
Average	1.62	1.90	1.97	1.87
	Feed efficiency (T.D.N./100 lb. gain)			
	Experiment 1			
1	519	499	554	640
2	447	503	494	554
2	443	487	544	577
4	458	493	525	587
5	460	484	518	543
Average	465	493	527	580
	Experiment 2			
1	503	542	553	585
2	493	496	576	580
3	476	479	500	605
4	497	473	524	561
5	489	453	487	554
Average	492	489	528	577

proportion of concentrate to include in the ration. However, since the proportion of grain and hay in the ration influenced dressing percentage and carcass grade, rate and efficiency of live weight gains should not be the only considerations in deciding upon the most economical ration to feed.

The steers which were fed their concentrate in the ground form (Lot 4, Experiment 1) consumed less feed per day, made slower daily gains, and were less efficient in utilization of feed than the steers fed their concentrate in pelleted form (Lot 3, Experiment 1). However, these differences were not statistically significant ($P=0.05$). In Experiment 1 there were no differences in average daily gain, feed efficiency, dressing percentage, carcass grade, or amount of fat in the carcass between the lot fed its entire ration in a pelleted form (Lot 5) and the lot fed the same ration but with the concentrate pelleted and the hay chopped (Lot 3). However, in Experiment 2, the lot which was fed its entire ration in the pelleted form (Lot 3) made significantly ($P<0.05$) slower gains than the lot which was fed its concentrate in the pelleted form and its hay in the chopped form (Lot 4). There was no difference between these two lots in efficiency of feed utilization.

In both experiments the average daily gains and feed efficiencies of steers fed controlled amounts of feed (Lot 2, Experiment 1, and Lot 5, Experiment 2) were not significantly ($P<0.05$) different from those fed the same ration *ad libitum*. As was mentioned above, controlled feeding is not considered practical in the commercial fattening of cattle, but it is used in performance and progeny testing where the emphasis is upon feed efficiency.

Daily Gain and Feed Efficiency as Influenced by Weight of Steer

Since all steers were fed individually and weighted at weekly intervals in Experiment 1, and at 2-week intervals in Experiment 2, it was possible to study their rate of gain and efficiency of feed conversion as they became heavier. Table 3 shows the average performance of the steers in each lot and in each experiment at 100-lb. intervals between 500 and 900 lb. body weight. As the animals became heavier, their average daily gains increased but more feed was required per unit of gain. This may be accounted for, in part at least, by the fact that as the animals became heavier their daily maintenance requirements increased and a greater percentage of the increase in weight was fat (3).

Relative Performance of the Hereford and Aberdeen Angus Steer Calves Used in these Experiments

Although the performance of different breeds of cattle cannot be compared accurately on the basis of two experiments, the data obtained are presented to indicate that animals from different lines of breeding, if not breeds, differ in rate of gain and efficiency of feed utilization. Table 4 shows the average daily gains, average efficiencies of feed utilization, dressing percentages, carcass grades, and amounts of fat in the carcasses of the Aberdeen Angus and Hereford steers in each experiment when considered over the body weight range of 500 to 900 lb. The data in this table are the averages for the steers of each breed from the five lots in each experiment.

TABLE 4.—THE AVERAGE DAILY GAIN, FEED EFFICIENCIES, DRESSING PERCENTAGES, AND CARCASS DATA OF ANGUS AND HEREFORD STEERS BETWEEN 500 AND 900 LB. BODY WEIGHT

	Experiment 1		Experiment 2	
	Angus	Hereford	Angus	Hereford
Av. days on feed	227	206*	229	216
Av. daily gain (lb.)	1.82	2.01**	1.80	1.88
Av. daily feed intake (lb.)	15.6	15.0	15.8	15.1
Av. T.D.N./100 lb. gain (lb.)	540	468**	550	503*
Av. dressing percentage[1]	56.9	56.1	57.1	56.5
Av. carcass grade[2]	Med. A	Low A	Med. A	High B*
Av. % separable fat 9-10-11 rib section[3]	34	29*	40	36*
Av. % fat in "eye" muscle at 11th rib (D.M.B.)[4]	17.8	14.5	10.5	9.7
Av. depth fat over "eye" muscle at 11th rib (mm.)	13.7	13.4	13.6	14.0
Av. weight kidney fat (lb.)	15.3	8.6**	14.0	9.8**
Av. weight caul fat (lb.)	13.0	10.4**	13.9	11.6*
Area of "eye" muscle at 11th rib (sq. cm.)	94	93	88	86
Weight hide (lb.)	74	89**	75	91**

* Significantly different ($P<0.05$) from the corresponding value for Angus.
** Significantly different ($P<0.01$) from the corresponding value for Angus.
[1] Based upon final live body weight and cold carcass weight (kidneys and kidney fat removed).
[2] A—*Choice*, B—*Good* (11).
[3] Determined by mechanical separation in Experiment 1 and by specific gravity in Experiment 2.
[4] Dry Matter Basis.

In Experiment 1 the Hereford steers made significantly ($P<0.05$) faster gains and were significantly ($P<0.01$) more efficient in the utilization of their feed than the Angus steers. In Experiment 2 the Hereford steers did not gain faster than the Aberdeen Angus but required significantly ($P<0.05$) less feed per 100 lb. of gain. In both experiments the Aberdeen Angus steers had more caul and kidney fat and more fat in the 9-10-11 rib section than the Herefords. The Hereford steers had significantly heavier hides than the Aberdeen Angus Steers. In Experiment 1, there was no significant difference in carcass grades between the Aberdeen Angus and Hereford steers but in Experiment 2, the Aberdeen Angus steers had significantly ($P<0.05$) higher grading carcasses than the Hereford steers. There were no significant differences between the two breeds in dressing percentage, percentage of fat in the "eye" muscle, depth of fat over the "eye" muscle, or area of "eye" muscle.

It is well known that the caloric content of fat tissue is greater than that of muscle tissue (1) and that more feed is required to put on a unit weight of gain if the gain is mainly fat tissue than if the gain is muscle tissue. The average caloric values of the muscle tissue and fat tissue as separated mechanically in this experiment were 1.8 and 9.0 cal. per gm., respectively.

The correlation between average daily gains and separable fat in the 9-10-11 rib section was -0.325* and the regression coefficient of separable fat in the 9-10-11 rib section on daily gains was -0.013. The correlation between the T.D.N. required per 100 lb. gain and separable fat in the 9-10-11 rib section was $+0.368$* and the regression coefficient of

*$P<0.05$

separable fat in the 9-10-11 rib on T.D.N. required per 100 lb. gain was 3.8. If the percentage separable fat in the 9-10-11 rib section was used as an index of the total fat in the carcass (5) and on the basis of the above regression coefficients, the difference in the amount of fat in the carcasses of the Aberdeen Angus steers as compared to the Hereford steers could account for approximately 25 per cent of the differences in the gain and feed efficiency between the two breeds.

From the above data one should not conclude that Aberdeen Angus cattle are less efficient in the utilization of their feed than are Hereford cattle, for although the steers from the two Aberdeen Angus herds used in these experiments made less gain in body weight per unit of feed than did the Hereford steers, they converted more of their feed to fat tissue. If both breeds had been slaughtered when they had a constant percentage of body fat rather than at a constant live body weight, differences in feed efficiency probably would have been less.

REFERENCES

1. Blaxter, K. L., and J. A. F. Rook. The heat of combustion of the tissues of cattle in relation to their chemical composition. Brit. J. Nutrition 7·83–91. 1953.
2. Bloom, S., N. L. Jacobson, L. D. McGilliard, E. O. Heady, and P. G. Homeyer. Effect of various hay·concentrate ratios on production response and nutrient utilization of dairy cows. J. Dairy Sci. 38·614. 1955. (Abstract).
3. Callow, E. H. Comparative studies of meat. II. The changes in the carcass during growth and fattening and their relation to the chemical composition of the fatty and muscular tissue. J. Agr. Sci. 38·174-199. 1948.
4. Dowe, T. W., V. H. Arthand, and J. Matsushima. Ratio of concentrates to alfalfa hay in fattening rations for beef cattle. Nebraska Agr. Expt. Sta. Bull. 431. 1955.
5. Hankin, O. G., and Paul E. Howe. Estimation of the composition of beef carcasses and cuts. U.S.D.A. Tech. Bull. 926. 1946.
6. Irvin, H. M., J. C. Shaw, P. Saarinen, and L. A. Moore. Net energy versus T.D.N. in evaluating the efficiency of an all-alfalfa hay ration for milk production. J. Animal Sci. 10·947-960. 1951.
7. Keith, T. B., R. F. Johnson, and W. P. Lehrer Jr., The optimum ratio of concentrate to alfalfa hay for fattening steers. Idaho Agr. Expt. Sta. Bull. 290. 1952.
8. Keith, T. B., R. F. Johnson, and W. P. Lehrer, Jr. Optimum ratio of concentrate to alfalfa hay for steers as affected by protein level and method of feeding. Idaho Agr. Expt. Sta. Research Bull. 26. 1954.
9. Lofgreen, G. P., and W. N. Garrett. Creatinine excretion and specific gravity as related to the composition of the 9, 10, 11th rib cut of Hereford steers. J. Animal Sci. 13·496-500. 1954.
10. Loosli, J. K., R. F. Davis, and R. G. Warner. Studies on the productive value of roughages and concentrates for lactation. J. Dairy Sci. 38·797-804. 1955.
11. Maybee, H. J. Beef and veal grading in Canada. Can. Dept. Agr. Publ. 962. 1955.
12. Morrison, F. B. Feeds and feeding. 22nd ed. Morrison Publishing Co., Ithaca, N.Y. 1956.
13. Pahnish, O. F., C. G. Shillingburg, Jr., C. E. Safley, and E. B. Stanley. The effect of various concentrate to roughage ratios in fattening rations for yearling steers. Proc. West. Sec. Amer. Soc. Animal Prod.·46-51. 1951.

VARIABILITY IN THE NUTRITIVE VALUE OF FISH MEALS FOR GROWING CHICKENS[1]

T. M. MacIntyre

Canada Department of Agriculture, Nappan, Nova Scotia

[Received for publication July 9, 1956]

ABSTRACT

Studies were made of the variation in quality of commercial fish meals produced in the Atlantic Provinces of Canada. A chick growth method was used for estimating the protein quality of the fish meals. Forty different samples of fish meal were tested. Results indicate that there is considerable variation in the growth-promoting qualities of commercial fish meals. This variation in growth appears to be due to variation in the protein quality of the fish meals.

INTRODUCTION

Fish meal is used in poultry rations as a source of amino acids, water soluble vitamins and unidentified factors. The quality of fish meal proteins is known to be high, (4, 5). Fish meal is known to be a good source of vitamin B_{12}, (8), and contains some unidentified factors beneficial to growth (3).

The nutritive value of fish meals varies considerably. A number of theories have been postulated to explain this variation, all based on spoilage or damage to the proteins, vitamins or other factors, prior to, during, or after processing. Grau and Williams (7) have reviewed the literature on this subject and also compared a large number of fish meals as amino acid sources for the chick, but were unable to offer a clear explanation as to why fish meals vary in quality.

While considerable work has been reported on the quality of fish meals produced along the Pacific Coast of Canada (1, 2), no data are available on the variation in quality of fish meals produced along the Atlantic Coast of Canada. The investigations reported here were designed to obtain information on the variation in quality which occurs in commercial fish meals produced in this area.

MATERIALS AND METHODS

The fish meals used in this study were commercial preparations obtained from fish processors in the Provinces of New Brunswick, Nova Scotia, and Newfoundland. Forty samples from 14 different processors were tested. Sufficient information was available to classify the fish meals into those made from whitefish, oily fish, or redfish, but the number and proportions of different species within each class going into a meal could not be determined. There were 31 samples of meal made from whitefish, such as cod, haddock, pollock, cusk, hake, and flounders; 6 samples made from oily fish such as herring and catfish; 2 samples made from redfish; 1 sample of sweepings and dust from the dust collector during the drying of whitfish; and 2 samples made by mixing a number of meals in equal proportions. The sample numbers, classification and chemical analyses are presented in Table 1.

[1] Contribution from the Division of Poultry Husbandry, Experimental Farms Service.

TABLE 1.—FISH MEAL SAMPLE NUMBER, CLASSIFICATION ON THE BASIS OF KIND OF FISH USED, AND CHEMICAL ANALYSES

Sample no.	Kind of fish	Protein N × 6.25%	Ash %	Calcium %	Phosphorus %
1	W.F.[1]	61.8	24.3	8.7	4.4
2	O.F.	56.8	19.2	5.2	2.9
3	W.F.	61.5	22.9	8.3	3.4
4	W.F.	65.6	33.9	11.3	4.1
5	W.F.	60.5	34.2	12.1	4.3
6	W.F.	65.4	32.2	10.5	3.8
7	W.F.	63.4	32.2	11.1	3.9
8	W.F.	68.4	30.5	10.7	3.8
9	W.F.	60.1	35.5	12.5	4.3
10	W.F.	62.3	25.7	9.5	5.1
11	W.F.	68.4	20.8	7.5	3.2
12	W.F.	68.7	11.2	2.5	1.9
13	W.F.	60.7	28.3	10.2	5.3
14	O.F.	69.2	12.8	4.1	2.5
15	R.F.	58.0	25.5	9.2	4.5
16	W.F.	62.8	23.2	7.9	4.1
17	W.F.	61.4	24.2	8.3	4.3
18	[2]	39.5	44.3	15.5	1.9
19	W.F.	57.9	26.0	8.7	4.4
20	W.F.	58.1	24.6	9.8	3.9
21	W.F.	62.4	26.3	9.6	4.9
22	W.F.	66.6	20.3	6.9	3.7
23	O.F.	64.2	19.3	6.5	3.5
24	O.F.	66.9	8.7	2.4	1.8
25	W.F.	67.9	25.7	9.5	4.7
26	W.F.	62.6	28.7	11.0	5.3
27	R.F.	56.9	27.8	10.3	5.0
28	[3]	63.0	21.8	8.6	3.9
29	W.F.	69.8	18.4	5.9	3.3
30	W.F.	66.0	18.9	6.2	3.3
31	W.F.	68.2	18.1	6.5	3.3
32	W.F.	64.0	21.5	7.2	3.8
33	O.F.	64.0	18.5	6.1	2.7
34	O.F.	65.6	8.6	2.6	1.5
35	W.F.	64.0	22.0	6.5	5.0
36	W.F.	61.8	26.3	9.7	1.6
37	W.F.	56.7	26.8	11.9	1.7
38	W.F.	58.6	28.7	11.3	4.2
39	W.F.	65.6	25.4	10.0	4.1
40	W.F.	62.6	26.0	10.3	4.0
41	[4]	59.5	25.2	9.8	3.9
42	W.F.	51.6	31.8	14.3	4.4

[1] W.F.—*whitefish*; O.F.—*oily fish*; R.F.—*redfish*.
[2] Collections from dust collector during drying of whitefish.
[3] A mixture of equal proportions of all samples up to and including number 27, but excluding number 18.
[4] A mixture of equal proportions of samples number 36, 37, 38, 39, 40 and 42.

All of the meals, with one exception, were dried in steam jacketed or steam tube dryers. In some cases steam cookers and presses were used before the material was introduced into the dryers. One sample was dried in a flame dryer. This in itself is of little significance since Grau and Williams (7) have shown that the quality of fish meals produced by different processors from the same catch of fish may vary considerably, even when the same type of dryer is used by each processor. Thus some unknown factor in the drying process, such as temperature control or mechanical operation of the dryer, may affect the quality of the meal.

A chick growth method was used for estimating the protein quality of the fish meals. One-week-old New Hampshire × Barred Plymouth Rock cross-bred male chicks, which had been fed the control ration for the first week after hatching, were divided into weight groups from which the chicks were allotted proportionally to give experimental groups of equal weight. There were two groups of 20 chickens each per treatment. The chicks were maintained in electrically-heated battery brooders with raised screen floors. The experiments were continued for five weeks. Individual chick weights were recorded weekly.

Six trials were conducted. In Trials 1 to 4 there was one control ration and seven rations containing different fish meals. In Trial 5, samples 29, 30, 32, and 33 were samples of the same registration number obtained from one manufacturer at different times. In Trial 6, a single lot of fish meal purchased from one manufacturer was used, but meal from separate bags within the lot was used for each ration.

The composition of the basal mixture is presented in Table 2. This basal mixture was formulated so that the substitution of about 12 per cent of fish meal would give a ration containing 18 per cent crude protein and complete in all known nutrients necessary for chick growth. In all cases the substitution of fish meal was made at the expense of the total mixture. The control ration was made up to 18 per cent crude protein by adding 7 per cent of soybean oil meal (50 per cent) and 7 per cent of whitefish meal (65 per cent) to 86 lb. of the basal mixture. One-half of 1 per cent of finely ground limestone was added to maintain the calcium level. One hundred lb. of soybean oil meal and 100 lb. of whitefish meal were reserved and used for the control ration in all trials.

In the experimental rations, 10 to 13 per cent of fish meal was used, depending on the protein content of the meal. The fish meal supplied

TABLE 2.—COMPOSITION OF BASAL MIXTURE

Ingredients	Amount (lb.)
Ground wheat	42.0
Ground corn	8.3
Ground oats	16.8
Ground barley	8.3
Wheat middlings	8.3
Wheat bran	8.3
Alfalfa leaf meal	5.0
Ground limestone	1.0
Bone meal	1.0
Iodized salt	0.5
Fish oil 1500 A, 300 D	0.5
Manganese sulphate	6 gm.
Riboflavin	160 gm.
Total (lb.)	100.0
Calculated analyses	
Crude protein %	12.2
Calcium %	0.77
Phosphorous %	0.58

TABLE 3.—MEAN BODY WEIGHTS OF 6-WEEKS-OLD CHICKENS FED RATIONS CONTAINING DIFFERENT FISH MEALS[1]

Trial 1			Trial 2			Trial 3			Trial 4			Trial 5			Trial 6		
Sample no.	Mean weight gm.	Per cent of control	Sample no.	Mean weight gm.	Per cent of control	Sample no.	Mean weight gm.	Per cent of control	Sample no.	Mean weight gm.	Per cent of control	Sample no.	Mean weight gm.	Per cent of control	Sample no.	Mean weight gm.	Per cent of control
Control	576		Control	590		Control	711		Control	684		Control	687		Control	626	
3	599	104	14	623	106	21	729	102	24	692	101	34	691	101	39	629	100
2	585	101	12	575	97	15	719	101	23	670	98	31	691	101	36	610	97
7	580	101	13	560	95	16	679	95	26	652	95	29	663	96	42	609	97
5	568	99	10	522	88	20	676	95	25	634	93	30	654	95	41	606	97
4	565	98	8	520	88	17	666	94	28	630	92	33	636	92	40	598	96
1	546	95	9	502	85	19	662	93	27	626	91	35	624	91	37	595	95
6	516	89	11	479	81	18	585	82	22	610	89	32	606	88	38	595	95
L.S.D. (0.01)	48			71			70			54			55			28	
(0.05)	34			56			50			38			39			34	

[1] The weights are expressed in grams, and in percentage of the mean weight of each control group.

about 40 per cent of the crude protein content of the diet. A crude protein level of 18 per cent was fed in preference to a higher level in order to put stress on the available protein and thus emphasize any difference in quality between samples of fish meal tested.

RESULTS AND DISCUSSION

Under the conditions of these experiments, commercially produced fish meals used as the major source of protein for growing chickens showed considerable variation in quality. Data presented in Table 3 show that in all trials where different fish meals were tested there were differences in body weight at six weeks of age between lots of chickens that received the best and the poorest fish meals. In Trial 5, where four of the samples tested (29, 30, 32, 33) were purchased under the same registration number from the same manufacturer but at different times, growth ranged from 96 per cent to 88 per cent of that on the control diet. This shows that fish meals of the same registration number may vary in quality from time to time.

This variation may be due to differences in the nature of the raw material such that similar methods of processing result in meals of different composition, or to processing procedures which differ sufficiently to produce differences in the composition of the final product or a combination of both. In Trial 6, where fish meal from different bags of the same lot of meal were tested, there was no significant difference between samples, suggesting that while there may be considerable variation in quality between fish meals of different registration number, and between samples of the same number manufactured at different times, any one lot is quite uniform.

All fish meals were analysed for crude protein ($N \times 6.25$), ash, calcium and phosphorus (Table 1). There was no correlation between any of these factors and the growth response. Total crude protein varied from 52 to 70 per cent, and ash from 8 to 34 per cent. Protein quality was not related to level of protein, an observation made by other workers (7).

Since no vitamin B_{12} was added to the basal mixture a study was made of high- and low-quality meals supplemented with crystalline vitamin B_{12} to determine whether the vitamin B_{12} content of the fish meals was affecting the results. The addition of vitamin B_{12} did not affect the growth response in any way. This is in agreement with the work of Tarr (9) which indicates that commercial fish meals are good sources of vitamin B_{12}.

These data show that great variation exists among fish meals made from a mixture of different species of fish and known broadly as whitefish meal or fish meal. It is unlikely that variation in the species of fish going into the meal would have any serious effect on protein quality since Dunn *et al.* (6) have shown that the muscle proteins in various species of fish have similar amino acid composition. However, in some cases there may be sufficient variation in the relative amount of muscle protein to total protein in fish meals to give differences in protein quality. Grau and Williams (7) have shown that any one species of fish may give meals of high or low quality. It is, therefore, not surprising to find that the fish meals used in this study and made from various species of fish in varying proportions also show variation in quality.

The basal ration used in this study was designed to supply adequate amounts of unknown growth factors and vitamins of the B complex including folic acid, which was found to be deficient in some commercial fish meals by Tarr *et al.* (10). Therefore, the variations in growth noted in these experiments must be attributed largely to variations in the protein quality of the meals under study.

CONCLUSIONS

The results of these experiments show that commercial grade fish meals produced in the Maritime Provinces vary considerably in growth-promoting quality for growing chickens, confirming observations made by many workers on fish meals produced in other regions. Growth rate on diets in which the different fish meals supplied approximately 40 per cent of the crude protein varied from 106 to 81 per cent of that on the control diet. Differences were noted between different brands of fish meal as well as between different batches of the same brand of meal produced at different times. Thus, brand name or registration number is no guarantee of uniform quality. The data presented suggests that the variation in growth is due to variation in the quality of the protein present in the fish meals.

ACKNOWLEDGEMENT

The author wishes to express his appreciation to the Nova Scotia Research Foundation, (H. D. Smith, President), for providing laboratory assistance for this work.

REFERENCES

1. Biely, Jacob, B. E. March, and H. L. A. Tarr. The nutritive value of fish meal and condensed fish solubles. VI. An unidentified growth factor(s) in fish meal. Progress Rept. Pacific Coast Sta., Fisheries Research Board Can. 92 : 10-13. 1952.
2. Clandinin, D. R. The effects of methods of processing on the nutritive value of herring meals. Poultry Sci. 28 : 128-133. 1949.
3. Combs, G. F., G. H. Arscott, and H. L. Jones. Unidentified growth factors required by chicks and poults. III. Chick studies involving practical-type rations. Poultry Sci. 33 : 71-79. 1954.
4. Deuel, H. J., Jr., M. C. Hruhetz, C. H. Johnson, R. J. Wingler, E. Geiger, and G. Schnakenberg. Studies on the nutritive value of fish proteins. I. Evaluation by the rat growth method and by the Cannon Method. J. Nutrition 31 : 175-185. 1946.
5. Deuel, H. J. Jr., M. C. Hruhetz, C. H. Johnson, H. S. Rollman, and E. Geiger. Studies on the nutritive value of fish proteins. II. The use of mackerel protein in the bioassay test for vitamin A. J. Nutrition 31 : 187-192. 1946.
6. Dunn, M. S., M. N. Camien, S. Eiduson, and R. B. Malin, The nutritive value of canned foods. I. Amino acid content of fish and meat products. J. Nutrition 39 : 177-185. 1949.
7. Grau, C. R., and M. A. Williams. Fish meals as amino acid sources in chick rations. Poultry Sci. 34 : 810-817. 1955.
8. Lillie, R. J., H. R. Bird, J. R. Sizemore, W. L. Kellogg, and C. A. Denton. Assay of feedstuffs and concentrates for vitamin B_{12} potency. Poultry Sci. 33 : 686-691. 1954.
9. Tarr, H. L. A. The nutritive value of fish meal and condensed fish solubles. V. The vitamin B_{12} content of herring meals. Progress Rept. Pacific Coast Sta., Fisheries Research Board Can. 90 : 10-15. 1952.
10. Tarr, H. L. A., J. Biely, and B. E. March. The nutritive value of herring meals. I. The effect of heat. Poultry Sci. 33 : 242-250. 1954.

VARIOUS COMBINATIONS OF GRASS SILAGE AND HAY FOR DAIRY CATTLE[1]

J. W. G. Nicholson and R. C. Parent[2]
Canada Department of Agriculture, Charlottetown, P.E.I.

[Received for publication February 13, 1956]

ABSTRACT

Rations, of which the roughage portion was grass silage, or grass silage with hay at three different rates ($\frac{1}{3}$, $\frac{2}{3}$, and 1 lb. hay per 100 lb. body weight daily), were compared in feeding trials with lactating Ayrshire cows over a 3-year period at the Experimental Farm, Charlottetown, P.E.I. No significant differences were found in milk production, change in body weight, or butterfat content of the milk. There were progressive increases in total digestible nutrients and dry matter consumption as the rate of hay feeding increased. These increases were significantly greater for higher rates of hay feeding. Possible causes of these increases in consumption are discussed.

INTRODUCTION

The humid climate of the Atlantic Provinces favours the growth of grasses and clovers but renders their preservation as hay somewhat hazardous. For this reason, great stress has been laid, in recent years, on the preservation of grasses and clovers as silage.

Much advice regarding the feeding of grass silage has been the result of observation only and has not been supported by experimental evidence. This was particularly true regarding feeding silage alone and in combination with hay. Since this experiment was initiated at Charlottetown, several reports have appeared in the literature. Blosser and co-workers (1) fed silage as the only roughage to dairy cows for three consecutive years during the winter months. The cows stayed on feed, looked well, and produced normally. However, more dry matter was consumed when some hay was fed along with the silage and more milk was produced. Newlander and co-workers (7) also reported silage alone was satisfactory for cows, while Cunningham (3), working with beef cows, reported silage alone was superior to hay alone but not quite as good as a combination of both. Alfalfa harvested as chopped hay, baled hay, loose hay, and silage was compared at Montana and reported by Keyes and Smith (4). The silage-fed cows produced more milk per pound of protein, total digestible nutrients, and total roughage consumed. Little and co-workers (5) reported no significant differences between silage and well-cured hay when both were harvested at the same time.

MATERIALS AND METHODS

Twelve lactating Ayrshire cows allotted to three groups of four animals each were used in each of three years to determine the comparative feeding value of grass silage alone and with hay fed at various rates. The double change-over design, as outlined by Cochran *et al.* (2), was used. The general plan of periods, rations and cow groups each year was similar to the following design in which A, B, C, D refer to rations:

[1] Contribution from Animal Husbandry Division, Experimental Farms Service. Presented before the Eastern Canadian Society of Animal Production, Quebec, Que., June 7, 1955.
[2] Agricultural Research Officer, and Superintendent, respectively.

Periods	Groups											
	Cows				Cows				Cows			
	1	2	3	4	5	6	7	8	9	10	11	12
I	A	B	C	D	A	B	C	D	A	B	C	D
II	B	A	D	C	D	C	B	A	C	D	A	B
III	C	D	A	B	B	A	D	C	D	C	B	A
IV	D	C	B	A	C	D	A	B	B	A	D	C

Each experimental period was of four weeks' duration with preliminary change-over periods of one week. Water was available in automatic water bowls. The cows were milked twice a day and weighed at the beginning and end of each period. They were allowed to exercise in a paddock for a short period on all fine days. Wood shavings were used as bedding.

All cows received one pound of meal mixture for every four pounds of 4% Fat-Corrected-Milk produced. The meal mixture consisted of: 375 lb. oats; 250 lb. barley; 100 lb. wheat bran; 75 lb. linseed oil meal, and 20 lb. mineral mixture. The roughages were good quality mixed grass-legume hay and silage composed chiefly of timothy, orchard grass and red clover, the proportions of which varied slightly from year to year. While the hay and silage were not cut from the same field, they were selected to have approximately equal proportions of legumes to grasses. The silage and hay were cut at the normal times, that is, silage was harvested when bloom began to appear on the clovers but haying was delayed until past full bloom. This was done so that the roughages used would be similar to those fed in actual practice. The roughages were fed according to the following plan:

Treatment A—Silage to appetite.
Treatment B—Hay, $\frac{1}{3}$ lb. per 100 lb. live weight + silage to appetite.
Treatment C—Hay, $\frac{2}{3}$ lb. per 100. lb live weight + silage to appetite.
Treatment D—Hay, 1 lb. per 100 lb. live weight + silage to appetite.

The daily hay ration was fed in two parts and was offered before feeding silage. Hay not consumed an hour after feeding was weighed back and the silage was fed. Silage not consumed two hours after feeding was weighed back. Ration A, which does not include hay, had silage offered for two hours twice a day.

Records were taken of the amount of feed consumed, change in weight of cows, milk and butterfat produced, percentage butterfat, as well as observations on the health and condition of cows and quality of milk. Samples of the hay, silage and grain were collected periodically and composited for each experimental period for chemical analyses. Total digestible nutrients were calculated for each experimental period by applying digestibility figures obtained from Morrison's "Feeds and Feeding" (6) to the various proximate components as determined by the chemical analyses.

RESULTS AND DISCUSSION

The average results of the chemical analyses for dry matter, protein and crude fibre for each year are presented in Table 1. Each value is the average of four periods.

TABLE 1.—CHEMICAL ANALYSES OF FEEDS—AVERAGE FOR EACH YEAR

	Dry matter			Protein (on a D.M. basis)			Crude fibre (on a D.M. basis)		
	1952-3	1953-4	1954-5	1952-3	1953-4	1954-5	1952-3	1953-4	1954-5
	%	%	%	%	%	%	%	%	%
Hay	94.8	93.4	93.0	8.5	9.0	8.5	38.5	36.7	35.3
Grain	93.2	91.8	90.2	15.3	16.6	15.0	10.3	9.0	9.4
Silage	26.1	27.2	22.2	11.7	12.5	13.0	33.7	32.3	35.0

Since there were no significant differences between years in any of the factors studied, the three years' data were combined for statistical analyses. As indicated in Table 2, there was no significant difference between any of the rations in terms of Fat-Corrected-Milk (F.C.M.), butterfat percentage, or change in body weight. There was a progressive increase in the consumption of dry matter (D.M.) and apparently of total digestible nutrients (T.D.N.) as the level of hay feeding increased. The consumption of hay and silage for the different rations as the average per cow per experimental period of 28 days is also shown in Table 2. The data indicate that, as the rate of feeding hay increased, there was a progressive decrease in the amount of silage replaced by a pound of hay.

TABLE 2.—SUMMARY OF RESULTS OF FEEDING GRASS SILAGE ALONE AND WITH HAY AT THREE DIFFERENT RATES EXPRESSED AS AVERAGES PER COW PER EXPERIMENTAL PERIOD OF 28 DAYS

		Rations			
		A	B	C	D
		Silage alone	Silage + Hay $\frac{1}{3}$ lb.	Silage + Hay $\frac{2}{3}$ lb.	Silage + Hay 1 lb.
Grain consumed	lb.	211	211	212	218
Silage consumed	lb.	2161	1852	1605	1401
Hay consumed	lb.	—	96	190	284
Total D.M. consumed	lb.	725	735	779[1]	811[2]
Total T.D.N. consumed	lb.	494	496	519[3]	536[4]
4% F.C.M. produced	lb.	797	784	784	790
Butterfat percentage		4.42	4.40	4.41	4.45
T.D.N. req'd per 100 lb. 4% F.C.M.	lb.	62	63	66	68[5]
Change in body weight	lb.	+8.8	+8.5	+5.1	+4.6
Silage replaced by 1 lb. of hay	lb.	—	3.22	2.93	2.68

[1] Significantly greater than treatments A and B, ($P < 0.01$).
[2] Significantly greater than treatments A, B and C, ($P < 0.01$).
[3] Significantly greater than treatments A and B, ($P < 0.01$).
[4] Significantly greater than treatments A and B, ($P < 0.01$) and treatment C ($P < 0.05$).
[5] Significantly greater than treatments A and B, ($P < 0.05$).

Attention is drawn to the fact that the high silage ration maintained equal milk production and body weight on a lower dry matter and calculated T.D.N. consumption. In fact, while not statistically significant at the probability levels used for testing, body weight gains tended to decrease as the proportion of hay in the ration increased. Since the cows had equal production on the different rations, it should follow that the T.D.N. consumption on the ration showing the greatest weight gains would be the highest. This apparent discrepancy may be due to chance variation from the use of average figures for digestibility on the data from the chemical analyses of the feeds in computing T.D.N. Some indication of the seasonal variability in the feeds is given by the data in Table 1. However, a more logical explanation of the discrepancy between calculated T.D.N. consumption and performance is that the T.D.N. supplied from the silage was more efficiently utilized than that supplied from hay. This observation is supported by the data for T.D.N. required to produce 100 lb. of 4 per cent fat corrected milk.

The silage was fed after milking and in no case was any foreign taste, attributable to high silage feeding, discernible in the milk. The cows remained in good condition on all rations but it was noted that the cows on the all-silage ration showed a craving for dry roughage. This supports the observation of Blosser and his co-workers (1). No conclusions on the importance of this craving can be made from this experiment in view of the short-term periods in which the cows received a particular ration in the change-over design.

REFERENCES

1. Blosser, T. H., G. W. Porter, R. E. Lintall, A. O. Shaw, and U. S. Ashworth. The use of large amounts of silage in the dairy ration. Wash. Agr. Expt. Circ. 202. 1952.
2. Cochran, W. G., K. M. Autrey, and C. Y. Cannon. A double changeover design for dairy cattle feeding experiments. J. Dairy Sci. 24 : 937-951. 1941.
3. Cunningham, C. J. Grass silage, grass silage and hay, or hay for wintering beef cows. West Va. Agr. Expt. Bull. 369. 1954.
4. Keyes, E. A., and E. P. Smith. The effect on milk production of feeding alfalfa harvested and stored by four different methods. Montana Agr. Expt. Sta. J. Dairy Sci. 37 : 657. (Abstract). 1954.
5. Little, C. J., A. J. Norden, and A. R. Wolcott. Baled hay (field cured) compared with hay crop silage for winter feeding of dairy cows. Michigan State College Agr. Expt. Sta. Quart. Bull. Vol. 36, No. 2, pp. 212-218. 1953.
6. Morrison, F. B. Feeds and feeding. 21st ed. Morrison Publishing Co., Ithaca, N.Y. 1948.
7. Newlander, J. A., W. H. Riddell, and R. Fitzsimmons. Making and feeding grass silage in Vermont. Vermont Agr. Expt. Sta. Pamphlet 26. 1952.

A SIMPLE RESPIROMETER FOR SMALL ANIMALS[1]

C. B. Bailey[2], W. D. Kitts and A. J. Wood

The University of British Columbia, Vancouver, B.C.

[Received for publication July 25, 1956]

ABSTRACT

An apparatus for the indirect determination of basal metabolic rate has been described. Representative results using the Swiss albino mouse as an experimental subject are recorded.

INTRODUCTION

A great number of techniques have been described for the indirect measurement of basal metabolic rate. Closed circuit devices which measure volume or pressure changes in a closed system appear to be the most convenient for the small animals. Brody (1) and Swift and French (6) have reviewed the various techniques.

In the course of a detailed study of certain aspects of normal growth of mice, it became desirable to measure the metabolic rate of a large number of individual animals. The need for a simple, but rapid and accurate apparatus for this purpose soon became apparent. Since the familiar techniques did not appear to fulfil all of the above requirements a respirometer of original design was constructed. The object of this paper is to present a description of the design and operation of the apparatus and to give some experimental results obtained with it.

DESCRIPTION OF RESPIROMETER

The design adopted is a modified version of a device described elsewhere for studying the kinetics of certain oxidation reactions (7). It is similar in principle to the familiar Warburg respirometer, with the exception that measurements are made at constant pressure rather than at constant volume. In this respect it resembles the Barcroft respirometer. A diagrammatic representation of the apparatus is given in Figure 1.

The apparatus consists of four separate parts:

1. A glass burette (A) modified to the extent that an outlet tube (E) has been added below the lowest scale reading and the top has been pinched off to form a side arm immediately above the 20 cc. mark (Q).

2. A U-tube manometer (B) of 5 mm. inside diameter, each arm of which is equipped with a glass stopcock (C and D) and a short side arm (G and H).

3. Two identical pyrex glass vessels (J and K) fitted with lids having ground glass seals. Each lid has two outlet tubes.

4. A cylindrical animal cage (N) of $\frac{1}{4}$-inch mesh hardware cloth, 4 cm. deep and 6 cm. in diameter, equipped with a metal droppings pan.

In operation the parts are assembled as shown in Figure 1.

[1] Contribution from the Division of Animal Science, University of British Columbia, Vancouver, B.C.

[2] Graduate Student; recipient of National Research Council of Canada studentship while engaged in this investigation.

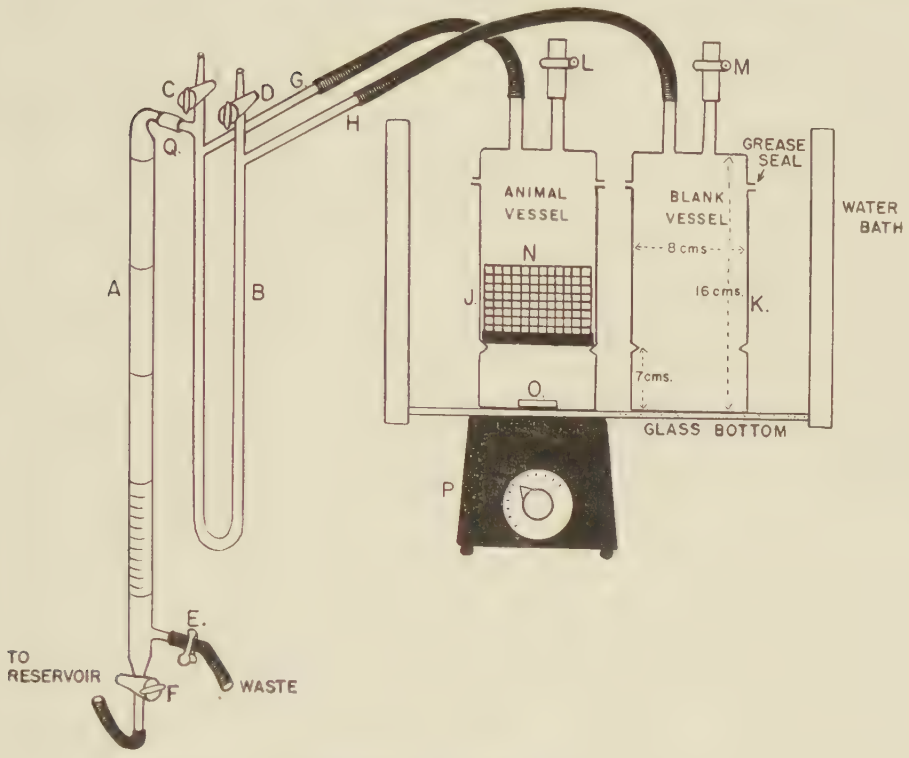

FIGURE 1. A diagrammatic representation of the respirometer.

METHOD OF USING RESPIROMETER

The animal is enclosed in N, then placed in J for temperature equilibration (20 minutes) during which time water is led from a reservoir to F. At the end of 20 minutes an equal aliquot of potassium hydroxide is added to J and K, and they are flushed with oxygen through C and D, with L and M open. In the present work A was not flushed but may be by opening E while C and D are open. E is closed; water is admitted through F to the lowest scale reading on A; then C, D, L and M are closed. The expired carbon dioxide is absorbed by the potassium hydroxide solution which is constantly agitated by a magnetic bar (O) maintained in constant rotation by a magnetic stirring motor (P) placed beneath the glass bottom of the water bath. The net pressure drop in the system causes the water levels in the manometer to be displaced from the rest position. Periodic restoration of pressure to atmospheric conditions, by allowing water from the reservoir to enter at F, permits a direct reading from the burette of the volume of oxygen used by the animal in the given time interval.

The volume of carbon dioxide produced by the animal is determined by titration of the potassium hydroxide solution in the animal vessel to the phenolphthalein and methyl red end points. From these values, and from the total volume of oxygen consumed, the respiratory quotient for the total test period may be calculated. The heat produced may then be

estimated by reference to standard tables showing the caloric equivalent per litre of oxygen or carbon dioxide. In order to compute heat production for any interval of time within the total period, the over-all respiratory quotient must be assumed to hold during that interval. Over short-time intervals this assumption is unlikely to introduce any errors of significance, since small variations in the state of activity of the animal cannot be expected to lead to measurable effects on the respiratory quotient.

It should be noted that the animal is breathing essentially pure oxygen. Over the short-time intervals used for the measurements no detectable difference could be noted between oxygen consumption or carbon dioxide production when the jar atmosphere was air or oxygen. For longer periods of observation it may be desirable to use a suitable gas mixture which will not affect the respiratory exchange.

The major advantage of the apparatus lies in its simplicity of operation. It takes but a few minutes to place the animal within the vessel and to then assemble the parts. Furthermore, by the simple expedient of subtracting the burette reading at any instant from the previous reading, the volume of oxygen used in any given time-interval is obtained directly. It is thus possible, by observing the animal, to eliminate from consideration the oxygen consumption during periods of activity.

By changing the sizes of the burette and the vessels and the concentration of the potassium hydroxide solution, animals of various sizes can be accommodated. For the larger laboratory animals it may be necessary to vary either the size of the manometer or the density of the manometer fluid in order that the levels in the manometer be not displaced to an extreme degree. Finally, by having a battery of respirometer units it is possible to measure the gaseous exchange of several animals simultaneously.

RESULTS AND DISCUSSION

The adequacy of the respirometer for the measurement of metabolic rate has been determined, using Swiss albino mice. Several hundred metabolic rate determinations have been made. For present purposes it may suffice to illustrate the use of the apparatus by describing certain of the preliminary validation experiments that were carried out.

Since the maintenance of a constant temperature in the animal vessel is a first essential, measurements were made to compare the ambient air temperature surrounding the mouse within the vessel with that of the water in the thermostated bath. A copper-constantine thermocouple was used. After temperature equilibration (20 minutes) fluctuations of ambient air temperature from bath temperature never exceeded 0.3° C. (always in the positive sense) over experimental periods of 1.5 hours. This difference was within the range of accuracy of the thermostatic control on the water bath.

To determine the point of thermal neutrality for the post-absorptive mouse, metabolic rate determinations were made at nine different temperatures between 22.7° and 35° C. The metabolic rate per gram of body weight declined from 0.270 Cal. per day at 22.7° C., to 0.168 Cal. at 30° C., and thereafter rose to a high of 0.268 Cal. at 35° C., at which temperature the animals exhibited signs of acute heat stress. The results

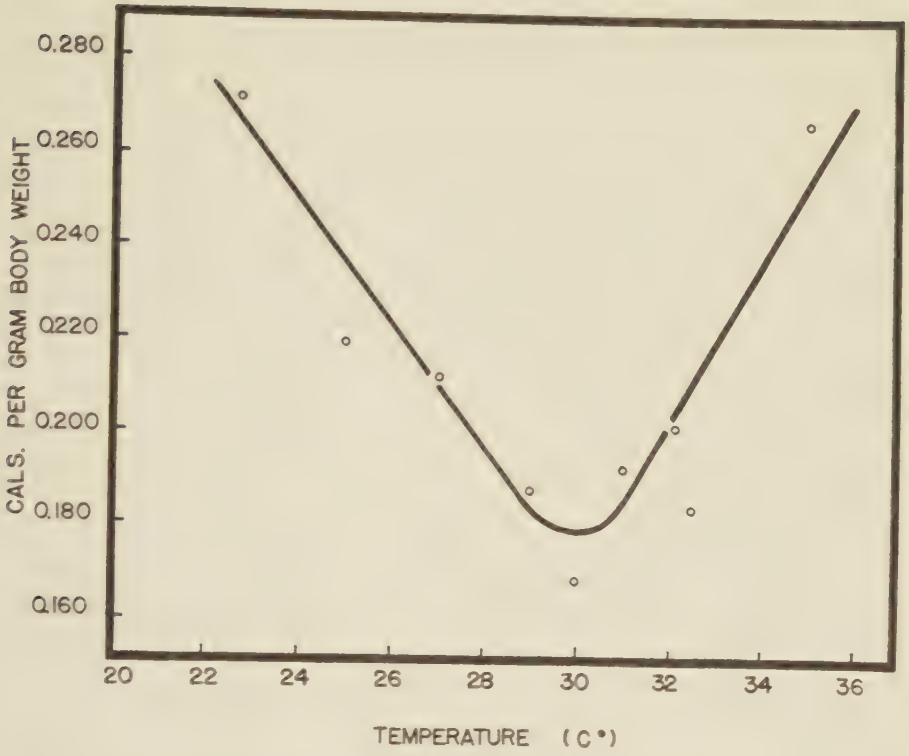

FIGURE 2. The relationship between environmental temperature and heat production per 24 hours for Swiss Albino mice.

are shown in Figure 2. It is apparent that the temperature of thermal neutrality for these animals is about 30° C. The very narrow range (about 29° C. to 31° C.) is very striking. These values corroborate results reported elsewhere for the same species [4]. It has been established that the point of thermal neutrality is a function of the previous environmental temperature and, as a result, is subject to some fluctuation [5]. The values obtained here are applicable to mice maintained at an environmental temperature of 26° ± 2° C.

By definition, metabolic rate determinations must be recorded when the subject is in a state of complete rest. To ascertain the effect of activity on the metabolic rate of the mouse a series of determinations were carried out on animals ranging in weight from 7.4 gm. to 27.4 gm. Considerable difficulty was encountered in obtaining a state of complete rest in mice with a body weight below 16 grams, if food was withheld for a period longer than 12 hours. Heavier, and hence older, mice could be fasted for a longer period. Because of this difficulty it was necessary to use a 12-hour fasting period and assume that the post-absorptive state had been reached in this time. For this purpose three activity states were defined. "Awake" designates that state where physical activity is readily apparent; "quiet" when the animal exhibits little movement but is not asleep; and "sleeping"

TABLE 1.—THE HEAT PRODUCTION OF FOUR REPRESENTATIVE MALE MICE IN RELATION TO AGE, BODY WEIGHT AND PHYSICAL ACTIVITIES*

Animal number	1	2	3	4
Age in days	15	23	26	45
Body weight (gm.)**	7.4	15.1	21.3	27.4
R.Q. (Sleeping)	0.78	0.79	0.73	0.81
HEAT PRODUCTION (Cal./24 HOURS)				
(Awake)		7.69±0.73	9.56±1.32	11.51±0.54
(Quiet)	3.51±0.38	5.42±0.56	6.52±0.52	7.44±0.22
(Sleeping)	2.64±0.23	4.35±0.22	5.35±0.35	5.93±0.23
Computed from the equation BMR = $70.5W^{0.73}$	1.96	3.36	4.25	5.10
Per gm. body weight per day	0.342	0.285	0.248	0.212
Per sq. meter body surface per day***	750.0	777.0	779.0	720.0

* Based on 8 determinations on each animal.
** Body weight recorded after 12-hour fast.
*** Surface area = $9W^{0.66}$.

when the animal shows no movement and when its eyes are closed. The results of these determinations are presented in Table 1. The values during the quiet and active states vary considerably, whereas they are relatively constant when the animal was asleep. The basal metabolism values (sleeping state) are very close to those reported elsewhere for the white mouse (2, 3). For animals approaching the mature weight the heat production approximates that value which may be calculated from the expression relating basal metabolic rate to body weight for mature animals of all species (1).† The reproducability of the replicate readings and the closeness with which these results parallel the values reported elsewhere tend to confirm the suitability of the apparatus for the indirect determination of heat production.

REFERENCES

1. Brody, S. Bionergetics and growth. Reinhold Publ. Corp., New York, N.Y. 1945.
2. Davis, J. E., and H. B. Van Dyke. The oxygen consumption of fasting white mice. J. Biol. Chem. 100 : 455-462. 1933.
3. Hart, J. S. Interrelations of daily metabolic cycle, activity and environmental temperature of mice. Can. J. Research (D) 28 : 293-307. 1950.
4. Herrington, L. P. The heat regulation of small laboratory animals at various environmental temperatures. Amer. J. Physiol. 129 : 123-139. 1940.
5. Schwabe, E. L., F. E. Emery, and F. R. Griffith. Effect of prolonged exposure to low temperature on basal metabolic rate of the rat. J. Nutrition 15 : 199-210. 1938.
6. Swift, R. W., and C. E. French. Energy metabolism and nutrition. Scarecrow Press, Washington, D.C. 1954.
7. Wright, R. H. Kinetics of the oxidation of sulphate black liquor. Tech. Assoc. Pulp and Paper Ind. 35 : 276-280. 1952.

† B.M.R. = $70.5W^{0.73}$

OPEN-VS. CLOSE-FACED SHROPSHIRES[1]

G. M. Carman and S. B. Williams

Canada Department of Agriculture, Ottawa

[Received for publication October 31, 1955]

ABSTRACT

In 1948 the Shropshire ewe flocks at the Central Experimental Farm, Ottawa, Ontario, and Experimental Farm, Nappan, Nova Scotia, were divided on the basis of face cover into two lots of approximately 20 each. The lots with least face cover were bred to British type, open-faced rams; the lots with most face cover to close-faced, or American type rams. Each lot was bred to at least one ram, with the rams being changed, in so far as possible, each year. In the 7-year period, 11 rams of the open-faced type, and 13 of the close-faced type, were used at the two Farms. Three of the open-faced type were used at both Farms. Average weights of the ewes in the Ottawa flock were equal at time of division.

The open-faced type sired lambs were superior to the close-faced in birth weight, 14-day weight, 28-day weight, weaning weight, yearling weight, market weight, and age at marketing.

Average weight of both types of ewes increased during the test period, but the open-faced, British type group increased faster than the close-faced, American type.

There were no differences in fleece count in the two types at either Farm; but the open-faced type ewes had slightly heavier fleeces, this being significant in the Nappan flock only.

Within the limits of the flocks at these two Farms, the superiority of the open-faced, British type of Shropshire is illustrated. However, this type is considerably larger than the more common close-faced, American type, and at least part of the advantage shown may be due to "grading-up" to this larger type. Heterosis, resulting from such wide out-crossing, also may be a contributing factor.

INTRODUCTION

Certain disadvantages of a closed face in sheep, both on the range and in the feedlot, have frequently been reported. In range country, where the ewe is required to travel extensively to feed, the wool-blind ewe may not only suffer from malnutrition, but may stray and become easy prey for predators. Wool-blind lambs in the feedlot tend to be more timid and not feed so well as the more open-faced type. Excessive face cover must be removed by periodic clipping, an added cost in operations. Under farm flock conditions a closed face has been thought to be less serious.

In the Shropshire breed, selection in America has been for excessive face cover with a concomitant possible loss in many factors of economic importance. In Britain, some Shropshire strains have been maintained and selected along open-faced lines, and are credited with being superior to the American type in milking ability, robustness, scale, and vigour.

Therefore, it seemed desirable to compare the performance of the two types of Shropshires under farm flock conditions.

LITERATURE REVIEW

Wool covering on the face and extremities was desired by some of the early breeders of sheep, since it was thought that this covering was

[1] Contribution from the Animal Husbandry Division, Experimental Farms Service.

associated with heavier fleeces. Early papers by Marshall (2), and Spencer *et al.* (7), reported that open-faced Rambouillet ewes had heavier fleeces and body weights than had wool-blind ewes.

Terrill (8) found that Rambouillet ewes with open faces produced nearly 9 pounds more lamb per year than those with covered faces. There appeared to be a slight tendency for the more open-faced ewes to have lighter fleeces, heavier body weights, and fewer neck folds. A Texas (12) report on 4-year-old ewes showed that 94 per cent of open-faced Rambouillet ewes dropped lambs, as compared with 80 per cent with medium face covering and only 52 per cent from those classified as close-faced.

Lifetime production of 798 Rambouillet ewes at the Western Sheep Breeding Laboratory, Dubois, Idaho, was analysed by Terrill (9). Ewes with open faces produced 11.3 per cent more lambs and 11.1 more pounds of lamb per ewe bred than those with covered faces, while those with partially covered faces weaned 8.6 per cent more lambs and 7.7 more pounds of lamb than those with covered faces. This was accomplished despite the fact that three periodic clippings around the eyes were given the close-faced ewes annually.

The inheritance of head covering was reviewed by Miller (3). Agreement on the mode of inheritance was lacking. Ritzman (5), using crosses of Rambouillet with Southdown, Hampshire, Oxford, and Dorset, found no simple dominance for face cover characteristics.

Terrill and Hazel (10, 11) obtained estimates of heritability for face cover of 0.32 and 0.56 $\pm$ 0.05, respectively. These agreed closely with an estimate reported by Peters (4). A later estimate of 0.48 for this same characteristic was presented by Shelton *et al.* (6).

A small negative relationship between face cover and fleece weight was found in many of the references cited. Terrill (9) believes that this can partially be explained by the open-faced ewes weaning more lambs, and selection for fleece being less stringent on open-faced than on close-faced individuals. This, however, would not appear to be the case in the Texas data, since all figures were taken on yearlings.

MATERIAL AND METHODS

An experiment was undertaken in 1948 at the Central Experimental Farm, Ottawa, and the Experimental Farm, Nappan, N.S., to study the relative performances of two types of Shropshires. The existing flocks of Shropshires were divided into two Lots, Lot I being ewes with the least face cover, and Lot II being ewes with the most. Lot I ewes were mated to open-faced, English-type rams, while Lot II ewes were mated to standard, close-faced, American-type rams. Selection of replacement females was within lots. Each breeding lot at each farm consisted of approximately 20 ewes.

In the seven-year period covered by this report, 11 rams of the open-faced, and 13 of the close-faced type, were used at the two Farms. Three open-faced rams were imported and used at both Farms. The remaining eight were offspring of the imported individuals from experimental flock ewes, and selected along British lines of minimum face cover. Rams were rotated between Farms to hold down inbreeding.

TABLE 1.—MEAN BIRTH, 14-DAY, 28-DAY, WEANING, AND YEARLING WEIGHTS OF PROGENY FROM THE TWO TYPES OF SHROPSHIRE RAMS OVER A SEVEN-YEAR PERIOD

	Birth wt.—lb.				14-day wt.—lb.				28-day wt.—lb.				Weaning wt.—lb.				Yearling wt. lb.	
	No.[1] Ottawa		No. Nappan		No. Ottawa		No. Nappan		No. Ottawa		No. Nappan		No. Ottawa		No. Nappan		No. Ottawa	
Type I (Open-faced)																		
Male singles	40	11.08	35	9.86	40	20.46	34	17.94	38	27.25	34	25.53	29	80.72	34	72.3	—	—
Male twins	80	8.90	32	8.08	70	16.36	31	13.88	69	22.05	30	19.18	57	68.91	29	63.1	—	—
Female singles	35	10.55	31	9.08	35	18.85	29	17.94	35	25.63	29	25.63	35	69.34	31	67.6	—	—
Female twins	59	8.30	30	7.46	56	15.35	27	12.41	55	20.55	26	16.89	52	62.46	23	59.6	63[2]	99
Weighted average		9.41		8.66		17.30		15.95		23.27		22.09		69.00		66.3	—	—
Type II (Close-faced)																		
Male singles	35	9.30	20	8.77	31	17.58	20	17.19	30	23.87	20	24.13	22	61.14	19	70.6	—	—
Male twins	32	7.35	39	7.41	26	13.23	37	13.01	24	17.90	37	18.21	18	57.89	37	55.7	—	—
Female singles	51	8.43	30	8.42	48	16.08	30	16.15	46	21.89	28	23.38	40	53.90	29	61.7	37[2]	83
Female twins	34	6.79	46	6.60	33	11.58	46	11.35	31	14.72	44	15.69	29	51.86	44	51.6	—	—
Weighted average		8.01		7.56		14.80		13.77		19.92		19.39		55.48		57.8	—	—
Advantage of Type I		1.37*		1.10*		2.50*		2.18*		3.35*		2.70*		13.52*		8.50*		16*

* Significant at 1 per cent level.
[1] No. of lambs in each group.
[2] Includes twins and singles.

The ewes were maintained under typical Eastern Canadian conditions. The flocks were wintered indoors with good quality hay the principal roughage. Approximately four weeks prior to lambing, or about March 1, a half-pound of grain per ewe was added to the daily ration. In summer the ewes and lambs at both locations were grazed on good pasture. Lambs were weaned in early August, at which time the wether lambs of sufficient finish and a minimum of 80 lb. weight were marketed. Lambs not ready at that time were fed to proper finish before being marketed. All normal ewe lambs were retained until at least one year of age before selection was made of replacement stock. The ewes were field bred during the months of November and December. All ewes subject to wool blindness had the wool clipped away from the eyes at least three times each year.

Data on 629 lambs from 464 lambings, over a period of seven years on two Farms, were available for study. Birth weights, 14-day weights, 28-day weights, and weaning weights were available on all lambs. In addition, yearling weights were available on all females retained for flock replacements. Weights at parturition, at 28-days post partum, and at breeding were available for all ewes at Ottawa, and for two years at Nappan.

Grease fleece weights, and estimated grades, were obtained on all fleeces.

Face cover scores were obtained on all ewes as shearlings immediately prior to putting them into the breeding lots. Standards corresponded closely to those used by Terrill (9) and were as follows:—

1. No wool below the poll.
2. Wool to the eyes, but no wool in vicinity of the eyes; no danger of wool blindness.
3. Wooled below eyes, but eye area clean. Little danger of wool blindness.
4. Wooled below eyes; only a channel from eye to nostril not wooled. Wool blind when in full fleece.
5. Completely wooled.

Heritability of face cover was estimated by means of an intra-sire regression of daughter on dam as used by Lush (1).

RESULTS AND DISCUSSION

The lamb production of both types* of Shropshires is presented in Table I. The advantages in pounds in favour of the lambs from the open-faced ewes at Ottawa and Nappan, respectively, were statistically significant in all cases. All females which were raised at Ottawa showed a 16-lb. advantage for the Type I group yearlings.

Marketing data on the lambs at Nappan are presented in Table 2. The Type II lambs had a slightly higher dressing percentage than Type I; but in age at marketing and market weight, Type I lambs were significantly superior to Type II, weighing four more pounds at marketing, and going to market 30 days sooner. The variability in "A" grade carcass percentage was so great that no conclusions are possible.

Ewe fleece weights, body weights, and face cover, by type and Farm, are presented in Table 3. There is some evidence that the Type I flocks have the heavier fleece, but this was statistically significant in the Nappan

* For purposes of identification, the flocks bred to the open-faced, British-type rams will be designated *Type I*, while those bred to the close-faced, American-type rams will be designated as *Type II*.

TABLE 2.—MARKET DATA ON OPEN- AND CLOSE-FACED SHROPSHIRES.[1] 1948-1954

Year	Face type	No.	Av. age at weaning	Av. age at market	Average market weight	Average dressing per cent	Per cent Grade "A"
			days.	days.	lb.	%	%
NAPPAN							
1949	Open	7	149.5	192.0	82.3	40.3	28.6
	Closed	10	152.6	242.5	74.7	46.0	70.0
1950	Open	9	138.2	280.1	86.2	43.5	22.2
	Closed	14	137.3	326.8	83.9	46.5	85.7
1951	Open	14	125.7	196.8	85.6	44.6	71.4
	Closed	13	120.8	207.0	81.2	45.2	69.2
1952	Open	8	135.0	304.5	80.4	45.8	25.0
	Closed	12	129.4	327.4	76.3	43.7	18.2
1953	Open	9	84.4	201.5	87.6	45.1	100.0
	Closed	16	119.1	262.4	84.1	45.2	88.2
1954	Open	11	122.5	157.6	83.3	44.2	63.6
	Closed	9	118.9	176.8	82.6	45.7	100.0
Weighted averages	Open		124.8	217.3*	84.5*	44.1	55.2
	Closed		129.0	262.3	80.8	45.4	72.0

* Difference significant at the 1 per cent level.
[1] All lambs shipped when 80 lb. in weight and having sufficient finish.

TABLE 3.—BODY WEIGHTS, FLEECE WEIGHTS, AND FACE COVER OF EWES BY YEAR AND TYPE

Face type	Body weight[1]-lb.				Fleece wt.-lb.		Face cover score	
	No.	Open	No.	Close	Open	Close	Open	Close
OTTAWA								
1948	19	111.5	24	110.9	5.5	5.6	2.11	2.80
1949	32	114.7	21	111.4	6.0	5.9	3.30	4.63
1950	23	138.5	29	128.1	6.7	6.9	—	—
1951	32	119.2	26	116.2	5.3	6.3	3.26	4.69
1952	21	139.5	19	122.2	6.9	6.0	2.71	4.29
1953	35	146.9	19	123.9	6.7	6.9	2.14	4.63
1954	42	141.7	16	131.3	6.6	6.4	3.12	4.47
NAPPAN								
1948	—	—	—	—	6.6	6.9	5.0	5.00
1949	—	—	—	—	8.1	6.1	4.3	5.00
1950	13	—	26	—	6.8	6.6	4.1	5.00
1951	16	—	22	—	6.5	6.3	4.3	5.00
1952	21	—	30	—	6.4	6.8	4.3	5.00
1953	26	131.8	26	118.5	7.7	6.9	4.9	5.00
1954	22	126.7	23	118.0	6.4	5.8	4.5	5.00

[1] Weight at parturition.

flock only. No differences in fleece count were observed between the two types at either Farm.

An average advantage of 10 pounds in body weight was shown for the Type I ewes at Ottawa. It was thought that this advantage might have resulted at the initial division of the flocks, but an examination of the figures presented in Table 3 shows that this was not the case. There is, however, a steady increase in the average weight of both types, with the increase being larger and more rapid in Type I. Yearly fluctuations are large and are probably due to changes in the quality of the roughage fed.

The open-faced British type is definitely larger in size, scale, and weight than the better known close-faced, or American type of Shropshire. Size differences between mature rams of the two types are considerable, and it is possible that the results obtained were due to this difference in

size rather than in face cover. Also, heterosis may be a contributing factor due to the wide out-crossing practised when using the British open-faced type rams on close-faced type ewes. However, eight of the Type I rams used were by the imported rams out of ewes in the experimental flocks, and this would tend to depress this effect.

Heritability of face cover was estimated to be $0.16 \pm .323$. This estimate is considerably lower than those presented in the review of literature. However, this may have resulted from the fact that the rams and ewes in the breeding flocks were only partially clean faced and the number studied was small. At Nappan, particularly, the relative differences in face cover were small, and changes in personnel at both Farms could possibly affect face classifications. Certainly, within the Shropshire breed, and in the sheep used, a single division on Terrill's (9) scale would indicate a considerable average difference between the flocks. The lack of progress made in removing the face cover from the Shropshires used would indicate that the heritability is not high.

REFERENCES

1. Lush, J. L. Intra-sire correlations or regressions of offspring on dam as a method of estimating heritability of characteristics. Amer. Soc. Animal Prod. 32 : 293-301. 1940.
2. Marshall, F. R. Experiments in breeding fine wool sheep. National Wool Growers 10 : 15. 1920.
3. Miller, W. C. A general review of the inheritance of wool characters in sheep. Empire J. Exptl. Agr. 1(2) : 173-192. 1933.
4. Peters, H. F. A study of Rambouillet sheep with special reference to face covering. B.S.A. thesis, University of Saskatchewan. 1945.
5. Ritzman, E. G. Wool covering on face, ears and legs. Agr. Expt. Sta. Tech. Bull. 37. 1928.
6. Shelton, M., J. C. Miller, W. T. Magee, and W. T. Hardy. A summary of four years' work in ram progeny and performance testing. J. of Animal Sci. 13 : 215-228. 1954.
7. Spencer, D. A., J. I. Hardy, and M. J. Brandon. Factors that influence wool production with range Rambouillet sheep. U.S. Dept. Agr. Tech. Bull. 85. 1928.
8. Terrill, C. E. Face covering in range sheep. U.S. Dept. Agr. A.H.D. 49. 1941.
9. Terrill, C. E. The relation of face covering to lamb and wool production in range Rambouillet ewes. J. Animal Sci. 8 : 353-361. 1949.
10. Terrill, C. E., and L. N. Hazel. Heritability of yearling fleece and body traits of range Rambouillet ewes. (Abstract). J. of Animal Sci. 2 : 358-359. 1943.
11. Terrill, C. E., and L. N. Hazel. Heritability of face covering and neck folds in range Rambouillet lambs as evaluated by scoring. J. of Animal Sci. 5 : 170-179. 1946.
12. Texas Agr. Expt. Sta. Annual Report, pp. 31-32. 1945.

NUTRIENT REQUIREMENTS FOR CANADIAN YORKSHIRE SWINE

I. A STUDY OF THE U.S. N.R.C. (1953) STANDARDS

J. M. Bell[1] (*Project Co-ordinator*)

In collaboration with:

J. P. Bowland[2], C. D. T. Cameron[3], E. W. Crampton[4], R. B. Carson[5], R. DePape[6], E. V. Evans[7], L. E. Lloyd[8], M. E. Seale[9] and A. J. Wood[10]

[Received for publication July 25, 1956

ABSTRACT

A co-operative nutrition project involving eight institutions across Canada was undertaken in order to test some of the swine feeding standards in the 1953 revision of "*Nutrient Requirements for Swine*". Four stations (University of British Columbia, University of Alberta, University of Manitoba, and the Experimental Farm, Nappan, N.S.) conducted swine feeding trials. Four rations were fed at each station: *A*—a centrally formulated barley ration based on the N.R.C. requirements for protein, Ca, P, vitamins A and D; *B*—a formula chosen by the co-operator; *C*—a ration based on the standards but employing barley plus oats as the basal grains, all ingredients being from local supplies; *D*—similar to ration C, but with barley plus wheat as the basal grains.

All feeds were analysed for crude protein, crude fibre, ether extract, ash, energy, Ca, P, weight/quart, riboflavin, niacin, choline and pantothenic acid. Carcasses were graded according to commercial grades and scored in detail according to Canadian Advanced Registry standards.

Approximately normal gains and feed efficiencies were obtained during the growing period (40-110 lb.) despite riboflavin, T.D.N. and pantothenic acid levels below the standards. Similar results occurred in the finishing period (110-200 lb.) but carcass quality proved to be unsatisfactory. It is suggested that the gains during the finishing period represented too much fattening in relation to skeletal and muscle development.

INTRODUCTION

Swine nutritionists in Canada have relied heavily upon United States research findings as guides for ration formulation and while for the most part this situation has been beneficial, it also has involved some risks. First, the Canadian market has been designed for the bacon trade, whereas the U.S. market has generally favoured the heavier, lard-type carcass. In the case of lard hog production, ability to promote rapid gains and high feed efficiency has been the main criterion of a good ration; but in producing bacon pigs something less than maximum gains and feed efficiency may be required in order to produce desirable carcasses.

Second, differences in the nutritional characteristics of corn, as against wheat and coarse grains, and differences between the components of typical protein supplements in the two countries create other difficulties in the adaptation of foreign data to local conditions.

[1] Professor of Animal Husbandry, University of Saskatchewan, Saskatoon, Sask.
[2] Associate Professor of Animal Husbandry, University of Alberta, Edmonton, Alta.
[3] Senior Animal Husbandman, Experimental Farm, Nappan, N.S.
[4] Professor of Nutrition, Macdonald College, Que.
[5] Head, Analytical Chemistry Unit, Division of Chemistry, Science Service, Canada Department of Agriculture, Ottawa, Ont.
[6] Formerly Assistant Professor of Animal Science, University of Manitoba, Winnipeg, Man.
[7] Associate Professor of Nutrition, Ontario Agricultural College, Guelph, Ont.
[8] Assistant Professor of Nutrition, Macdonald College, Que.
[9] Assistant Professor of Animal Science, University of Manitoba, Winnipeg, Man.
[10] Professor of Animal Husbandry, University of British Columbia, Vancouver, B.C.

TABLE 1.—FORMULAS AND ANALYSES OF GROWER RATIONS FOR PIGS UP TO 110 LB. LIVEWEIGHT

Feedstuff or nutrient	Ration A	Ration B				Ration C				Ration D			
	All stations	U.B.C.	U. of A.	U. of M.	Nappan	U.B.C.	U. of A.	U. of M.	Nappan	U.B.C.	U. of A.	U. of M.	Nappan
Barley, lb.	870	895	610	403	895	606	639	658	653	639	645	667	653
Wheat, lb.										210	215	223	217
Oats, lb.			250	402		220	213	217	217				
Linseed oilmeal, lb.			25	63									
Soybean oilmeal, lb.	57		62.5			79.5	66.5	55	57.5	68.5	62.5	47	57.5
Meat meal, lb.	58		30	90		79.5	66.5	55	57.5	68.5	62.5	48	57.5
Fish meal, lb.		90			90								
Alfalfa meal, lb.			10	27									
Salt, iodized, lb.	5	5	5	5	5	5	5	5	5	5	5	5	5
Ground limestone, lb.	5	5	5	5	5	5	5	5	5	5	5	5	5
Aurofac*, lb.	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Vitamin A, I.U./lb.	680	680	1000	680	680	680	850	680	680	680	680	680	680
Vitamin D, I.U./lb.	136	136	200	136	136	136	170	136	136	136	136	136	136
Chemical composition (on a 10% moisture basis)													
Crude protein, %	17.4	16.8	16.4	17.8	15.8	16.8	14.5	15.8	14.6	17.5	15.0	15.9	15.1
Crude fibre, %	4.5	5.4	8.9	7.2	3.7	5.6	7.3	6.0	5.7	4.5	7.0	3.7	3.7
Cal./gm.	3.78	3.89	3.73	3.85	3.70	3.80	3.74	3.80	3.63	3.80		3.83	3.65
Ether extract, %	2.0	2.5	3.5	3.9	2.1	2.4	2.2	2.3	2.2	1.9	2.4	2.1	2.0
Ash, %	3.6	4.5	4.7	7.5	5.3	4.3	6.4	6.6	7.1	2.5	5.7	5.8	6.6
N.-F.E., %	62.5	60.8	56.5	53.6	63.1	60.9	59.6	59.3	60.4	63.6	59.9	62.5	62.6
T.D.N. (est'd)**, %	69	68	68	65	68	68	68	68	68	72	72	72	72
Calcium, %	0.65	0.59	0.56	1.12	0.78	0.69	1.03	0.86	0.85	0.48	0.99	0.76	0.85
Phosphorus, %	0.63	0.47	0.50	0.68	0.69	0.65	0.74	0.62	0.57	0.60	0.74	0.63	0.59
Riboflavin, mg./lb.	0.7	0.9	0.7	0.8	0.7	1.0	0.7	0.8	0.7	0.9	0.7	0.8	0.7
Niacin, mg./lb.	34	42	31	20	43	29	30	27	27	34	35	33	32
Pantothenic acid, mg./lb.	2.1	3.6	1.8	2.1	1.7	3.0	1.8	1.9	1.9	3.2	2.0	1.9	1.9
Choline, mg./lb.	696	880	720	634	858	721	661	590	704	745	686	625	741
Wt./quart, lb.	1.02	1.16	1.31	1.06	1.56	1.09	1.07			1.17	1.15		

* To supply 10 gm. aureomycin/ton of feed.

** Based on Schneider's Tables in "*Feeds of the World*" (West Va. Agr. Expt. Sta., 1947).

The publication "*Recommended Nutrient Allowances for Swine (1944)*", and its subsequent revisions in 1950 and 1953 (11), have been of great value in Canada, particularly since they represented the most detailed and complete compilations of nutritional findings available at the time of issue. The 1953 issue, entitled "*Nutrient Requirements for Swine*", involved deletion of safety margins. The values presented were . . . "considered to be adequate for normal health, growth and productivity".

Recognizing (a), the possibility that inherent differences in both the feeding and breeding of swine might create problems in interpretation; (b), that the U.S. N.R.C. compilation represented the net result of amalgamation of research findings from many different experiments, and (c), that the data so assembled apparently had not been subjected to actual test in their final form to determine how well they described the 'ideal' ration, a co-operative experiment was undertaken to study the applicability of the "*Nutrient Requirements for Swine*" under Canadian conditions.

MATERIALS AND METHODS

Scope and Organization

The investigation was designed to test the responses of pigs in various parts of Canada to a standard, centrally-formulated barley ration, based on the N.R.C. "*Nutrient Requirements for Swine*". In addition to the standard ration, each co-operating institution designed a barley-oats and a barley-wheat ration, again according to the standards. Each institution also included a ration whose formula was of local choice.

Co-operating in the feeding phases of the project were the Universities of British Columbia, Alberta and Manitoba, and the Experimental Farm at Nappan, Nova Scotia. Formulation of the standard ration and co-ordination of the project were done at the University of Saskatchewan. Chemical analyses were conducted mainly by the University of British Columbia (U.B.C.), the University of Alberta, Macdonald College, the Ontario Agricultural College (O.A.C.), and the Chemistry Division of Science Service, Department of Agriculture, Ottawa. The Marketing Service, Department of Agriculture, Ottawa, conducted the carcass-scoring and grading.

Rations

Ration A was designed to meet the protein, calcium, phosphorus, vitamin A and vitamin D requirements of 50-lb. pigs during the growing phase and of 150-lb. pigs in the finishing period. The basal grain employed was No. 2 C.W. barley, which was obtained from one source and held in storage, as whole grain, until required. The protein supplements were linseed oilmeal and meat meal which were likewise purchased in quantity and stored to minimize variation in quality and composition. Salt, limestone, feeding fish oil and antibiotic feed supplements were purchased as required. The complete formulas for these rations are shown in Tables 1 and 2.

TABLE 2.—FORMULAS OF FINISHER RATIONS FOR PIGS FROM 110 TO 200 LB. LIVEWEIGHT

Feedstuff or nutrient	Ration A	Ration B				Ration C				Ration D			
	All stations	U.B.C.	U. of A.	U. of M.	Nappan	U.B.C.	U. of A.	U. of M.	Nappan	U.B.C.	U. of A.	U. of M.	Nappan
Barley, lb.	954	945	620	460	937	677	699	704	710	700	708	710	710
Wheat, lb.										232	236	233	237
Oats, lb.			310	458		256	233	234	237				
Linseed oilmeal, lb.			12.5	24.5									
Soybean oilmeal, lb.	16		30			27.5	27.75	25	20	28	21.75	23	20
Meat meal, lb.	16		12.5	35		27.5	27.75	25	20	28	21.75	22	20
Fish meal, lb.		43			50								
Alfalfa meal, lb.			5	10.5									
Salt, iodized, lb.	5	5	5	5	5	5	5	5	5	5	5	5	5
Ground limestone, lb.	5	5	5	5	5	5	5	5	5	5	5	5	5
Aurofac, lb.					2.5				2.5				
Vitamin A, I.U./lb.	900	1135	1000	680	680	680	850	680	680	680	680	680	680
Vitamin D, I.U./lb.	135	170	200	136	136	136	170	136	136	136	136	136	136
Crude protein, %	13.1	14.2	12.9	14.7	13.5	14.2	12.1	14.0	12.6	14.6	12.4	14.5	13.0
Crude fibre, %	4.5	4.3	8.0	8.0	4.1	5.7	7.7	6.3	5.9	5.0	7.3	3.9	3.7
Cal./gm.	3.79	3.82	3.72	3.76	3.68	3.81	3.79	3.86	3.72	3.78	3.55	3.88	3.74
Ether extract, %	2.2	2.1	2.2	2.9	1.9	2.0	2.5	2.1	2.0	1.5	2.0	1.9	1.9
Ash, %	2.6	4.0	4.3	5.7	4.7	3.1	4.4	4.9	4.6	2.9	3.7	4.3	4.0
N.-F.E. %	67.6	65.4	62.6	58.7	65.8	65.0	63.3	62.7	64.9	66.0	64.6	65.4	67.4
T.D.N., % (est'd)*	69	69	68	66	69	68	68	68	68	72	72	72	72
Calcium, %	0.35	0.59	0.52	0.60	0.50	0.40	0.51	0.44	0.38	0.25	0.44	0.41	0.39
Phosphorus, %	0.47	0.48	0.51	0.51	0.50	0.51	0.56	0.52	0.42	0.48	0.57	0.55	0.44
Riboflavin, mg./lb.	0.7	0.8	0.9	0.9	0.8	0.8	0.6	0.7	0.7	0.8	0.6	0.7	0.7
Niacin, mg./lb.	39	41	28	21	37	30	31	28	28	35	37	35	34
Pantothenic acid, mg./lb.	1.2	3.5	1.7	2.1	1.3	2.9	1.5	1.8	0.8	3.0	1.4	1.8	0.8
Choline, mg./lb.	678	872	692	589	765	592	651	575	690	729	676	613	731
Weight/quart, lb.	0.98	1.14	1.29	1.06	1.56	1.05	1.02	1.00	1.37	1.15	1.10	1.27	1.47

* Based on Schneider's Tables.

The grain for Ration A was ground and the mixing was done just prior to the commencement of each feeding trial so that storage losses would be minimized.

Ration B was entirely the responsibility of each co-operator and was therefore an attempt to subject local practices or recommendations to test in comparison with the N.R.C. standards. No prior restrictions were imposed on the selection of ingredients but it will be noticed that all four stations relied heavily on barley as the basal grain. Another point of interest is that the prairie stations used oats, vegetable oilmeals and meat meal, whereas the coastal areas employed barley and fishmeal as the main ingredients. All stations used supplementary minerals, antibiotics and vitamins A and D as in Ration A.

Ration C was designed to use a 3 : 1 mixture of 2 C.W. barley with 3 C.W. oats as the grains along with supplementary feeds as for Ration A, except that all ingredients were drawn from local supplies. The ration was formulated on the basis of the N.R.C. nutrient requirement standards.

Ration D was similar to Ration C, except that No. 1 Feed wheat replaced the oats in order to produce a higher energy ration.

Pigs and Management

At each station, four Yorkshire pigs (two barrows, two gilts) were allotted to each ration in two successive replicates. Thus eight pigs were tested on each ration at each of four feeding stations across Canada, except at U.B.C. and Nappan, where the tests remained incomplete because of unforeseen difficulties. All pigs were self-fed on a group basis.

The pigs went on test at an initial weight of 40 $\pm$ 3 lb. and under 75 days of age. Upon attaining an average weight of 110 $\pm$ 5 lb., each group was changed to the finishing ration and the pigs were slaughtered as they reached 200 $\pm$ 10 lb. liveweight. Regular weighings were made every two weeks throughout the feeding trial.

Upon slaughter the pigs were graded according to the Canadian Government Carcass Grading system and were carcass-scored according to the Advanced Registry standards to obtain detailed carcass measurements on length, fat deposition, balance and loin area.

Feedingstuffs Analyses

Crude protein, ash and crude fibre determinations were done according to the official methods of the A.O.A.C. (12), modified only in that the ammonia distillation for protein was into boric acid solution.

Ether extract was determined according to the multiple-extraction procedure described by Crampton (5).

Energy content was found with a peroxide bomb calorimeter, using the method recommended by the Parr Instrument Company (1).

The calcium method employed was that of McCance and Shipp (9) and phosphorus was determined according to King's (7) procedure.

Vitamin analyses were carried out by both U.B.C. and O.A.C. in the case of niacin and pantothenic acid. Only the latter institution determined choline. The methods were as follows:

(a) *Riboflavin.* U.B.C. assayed according to the procedures outlined by Barton-Wright (2) using basal medium No. 1 and the microorganism *L. helveticus* (*casei epsilon.*) Assay samples were extracted for 24 hours with 40-60° C. B.P. petrol ether prior to hydrolysis with 0. 1N HCl.

O.A.C. employed the method of Roberts and Snell (13) with extraction procedures as given by Strong and Carpenter (14). A number of samples were also assayed fluorometrically (12). The results reported in Table 1 and 2 are the averages of the values reported by the two stations.

(b) *Niacin.* U.B.C. followed procedures given by Barton-Wright (2) and used the organism *L. arabinosis* A.T.C. 15/5.

O.A.C. followed Roberts and Snell (13), used *L. arabinosis*, added a trace of Tween to the basal medium and extracted the samples according to the method of Krehl *et al.* (8).

(c) *Pantothenic Acid.* Both institutions employed the procedure given by Barton-Wright (2) and used *L. arabinosis* but O.A.C. used an acid rather than an enzymatic casein hydrolysate in the medium and used an extraction method reported by Novelli and Shmetz (10).

(d) *Choline* was determined according to a modification (4) of the method developed by Horowitz and Beadle (6).

RESULTS AND DISCUSSION

The results of chemical analysis of the feeds for the growing period are shown with the ration formulas in Table 1. The deviations in composition from the 'ideal' N.R.C. ration (Ration A) reflect errors incurred by formulating on the basis of a protein analysis and assumed values for other components. It will be noted that protein percentages for all rations varied from 14.5 to 17.8 per cent as against the objective of 16 per cent. Calcium ranged from 0.48 to 1.03 per cent in rations A, C and D and phosphorus in these cases varied between 0.59 and 0.74 per cent compared to 0.65 and 0.45 per cent for calcium and phosphorus, respectively, as minimum requirements. Thus in four of the rations there was less than the N.R.C. standard level of calcium.

The minimum level of riboflavin according to the standard is 1.0 mg./lb. From Table 1 it is apparent that in the case of only one ration was this level attained and in the majority of cases the level found was 0.7 mg./lb.

Conversely, 5 mg. of niacin per pound of feed represents the minimum according to the N.R.C. data and the rations were found to contain from 20 to 43 mg.—apparently well in excess of requirements. This situation was due largely to the use of wheat and barley in the rations.

Pantothenic acid contents ranged from 1.7 to 3.6 mg. per pound of ration and were, therefore, well below the N.R.C. requirement levels of 4.5 to 5.0 mg.

The choline requirements are indefinite for pigs beyond the normal suckling stage at which time they are stated to be 400 mg./lb., but with levels ranging from 590 to 880 mg. there is little likelihood of inadequacy in this regard.

TABLE 3.—RATES OF LIVEWEIGHT GAIN AND CARCASS CHARACTERISTICS OF PIGS FED RATION A COMPARED TO THOSE FED RATION B, BY STATIONS

Item	U.B.C.		U. of A.		U. of M.		Nappan		Standards
	A	B	A	B	A	B	A	B	
Grain components	Barley	Barley	Barley	Barley-Oats	Barley	Barley-Oats	Barley	Barley	
No. of pigs	4	4	8	8	8	8	8	4	—
Initial age of pig, days	66.5	66.0	69.2	70.5	64.6	64.4	57.8	55.7	75
Initial wt. of pig, lb.	44.0	40.8	37.1	37.6	39.3	39.1	39.3	39.8	40
Gain/day, 1st period, lb.	1.31	1.07	1.39	1.39	1.31	1.29	1.57	1.28	1.2—1.6
2nd period, lb.	1.56	1.29	1.50	1.73	1.95	1.71	1.97	1.58	1.6—1.8
Total period, lb.	1.41	1.23	1.45	1.54	1.60	1.50	1.76	1.43	—
Age at 200 lb., days	176	196	182	176	165	169	148	168	—
Dressing %, cold	78.5	76.3	75.6	75.0	76.9	77.5	76.1*	—	—
Carcass grades (A-B-C)	0-4-0	1-3-0	1-6-1	3-4-1	1-6-1	3-5-0	1-7-0	2-1-1	—
A.R. score	68.3	60.0	62.5	70.0	66.2*	67	67.2	71	75+
Length, in.	30.5	29.7	30.5	30.5	30.1	30.4	30.6	30.4	31
Fat, shoulder, in.	2.15	1.88	1.89	1.95	1.99	1.90	2.19	2.00	1.8
back, in.	0.93	0.85	1.10	1.02	1.17	1.00	1.11	1.20	0.9—1.0
loin, in.	1.43	1.25	1.50	1.47	1.58	1.45	1 67	1.70	1.0—1.2
Balance, shoulder, %	27.0	27.2	27.4	27.1	26.0*	27.1*	25.9	25.9	25
middle, %	50.1	50.0	48.7	48.9	48.6	48.3	50.7	50.1	50
ham, %	22.9	22.8	23.9	24.0	25.3	24.6	23.4	24.0	25
Loin area, sq. in.	4.21	4.39	3.15	3.55	3.80	3.62	3.89	3.86	3.90+
Feed/lb. gain, 1st period	4.39	3.12	2.94	3.21	3.54	3.94	3.00	3.21	2.7—3.3
2nd period	4.06	4.50	4.26	4.45	3.90	4.19	3.86	3.64	3.8—4.2
total period	4.26	3.92	3.61	3.86	3.75	4.08	3.46	3.45	ca. 3.4

* Data on four pigs only.

Inspection of Tables 3 and 4 indicates that, despite the possibility of a shortage of energy, pantothenic acid and riboflavin, the pigs gained an average of 1.31, 1.39, 1.31 and 1.51 pounds on ration A, at the four stations. These growth rates appear to fall within the 'standard' range of 1.2 to 1.6 for pigs between 50 and 100 lb. in weight.

Efficiency of feed utilization during the growing period varied from 2.9 to 4.4 lb. of feed per pound of gain on ration A with Alberta and Nova Scotia pigs utilizing feed within the efficiency range indicated by the standards (Table 3). In Table 4 it would appear that the average feed efficiency was below the N.R.C. values for each of rations A, C and D. It may be, of course, that this reflects the fact that T.D.N. values were below 75 per cent. However, out of the 21 groups of four pigs tested on N.R.C. standard rations, 4 groups had efficiency averages of below 3.0, and 14 groups averaged below 3.3 lb. of feed per pound of gain. U.B.C. pigs on Ration A showed mild symptoms of riboflavin and pantothenic acid deficiencies and produced the poorest efficiency of any station (4.4). There is a distinct possibility that storage losses were involved here, since Ration A was held for several weeks prior to feeding because of a delay in starting the project. Despite this single report of possible deficiency conditions, the good gains and feed efficiencies during the growing period of the majority of the test groups do not indicate that energy, calcium, pantothenic acid or riboflavin were much, if at all, below required levels.

During the finishing period (110-200 lb. liveweight) the protein contents of the rations varied from 12.4 to 14.7 per cent and therefore were slightly in excess of the N.R.C. values which vary, by weight intervals, from 12.0 to 14.0 per cent.

TABLE 4.—RATES OF LIVEWEIGHT GAIN AND CARCASS CHARACTERISTICS OF PIGS FED RATIONS (A, C AND D) FORMULATED BY N.R.C. STANDARDS

Item	Ration number			
	A	C	D	Standards[1]
Grain component	Barley	Barley-Oats	Barley-Wheat	
Initial age of pig, days	64.3	64.5	66.4	75
Initial wt. of pig, lb.	39.4	38.8	39.7	40
Gain/day, 1st period, lb.	1.39	1.22	1.31	1.2—1.6
2nd period, lb.	1.73	1.89	1.63	1.6—1.8
total period, lb.	1.57	1.51	1.47	—
Age at 200 lb., days	173	172	178	—
Feed/lb. gain, 1st period	3.34	3.53	3.51	2.7—3.3
2nd period	4.01	4.07	4.47	3.8—4.2
total period	3.69	3.82	3.97	ca 3.4
Dressing %, cold	76.6	76.0	76.1	—
Carcass grades (A-B-C)	3–23–2	14–12–2	9–16–2	—
A.R. score	65.7	68.9	68.2	75+
Length, in.	30.4	30.3	30.4	31
Fat, shoulder, in.	2.04	1.95	1.97	1.8
back, in.	1.10	1.03	1.08	0.9—1.0
loin, in.	1.56	1.53	1.54	1.0—1.2
Balance, shoulder, %	26.6	26.9	26.8	25
middle, %	49.6	49.2	49.3	50
ham, %	23.8	24.0	23.9	25
Loin area, sq. in.	3.68	3.76	3.65	3.90+

[1] Carcass measurements according to Advanced Registry standards; grades as obtained from sale of carcasses, others according to U.S. N.R.C. Publ. 295, "*Nutrient Requirements for Swine*", rev., 1953.

The calcium contents of the finishing rations proved to be below the standards for 100-lb. pigs in every case, which would indicate that there may be less calcium available in swine feed components than tables of composition show. Whether the low calcium during the finishing period was associated with depression in skeletal development and lowering of carcass grade is doubtful, but it may be worthy of further investigation.

There was very little deviation from standard values as far as phosphorus was concerned and no station reported any signs of rickets. The Nappan station, however, experienced a skin condition on the pigs in one replicate during the early part of the growing period on ration B. In view of possible mineral imbalance it might be noted that the calcium and phosphorus contents of that ration were 0.78 and 0.69 per cent, respectively; in excess of the standards by 20 and 53 per cent margins. Alberta also reported parakeratosis in rations C and D, second replicate, during the growing period. Several other rations contained higher levels of these minerals in similar or different ratios but they did not produce skin troubles.

Riboflavin continued to be below the standard values during the finishing period and this was also the case with pantothenic acid.

The performance of the pigs during the second period showed an average rate of gain of 1.7 lb. for ration A; 1.9 for ration C and 1.6 for ration D; compared to a 'standard' range of 1.6 to 1.8 lb., and they reached 200 lb. liveweight at 173, 172 and 178 days of age, respectively. Corresponding feed efficiency figures were 4.0, 4.1 and 4.5 lb. of feed per lb. of gain for ration A, C and D respectively.

Gains on the centrally formulated finishing ration (A) varied from 1.5 to 2.1 lb. per day, thus revealing station differences and indicating that gains in excess of N.R.C. rates are possible with rations formulated according to the standards.

Examination of the carcass data showed that the superior performance in terms of good feed efficiency and 'normal' rates of gain did not result in the development of a sufficiently high percentage of top grade carcasses. On ration A, for instance, only 10 per cent of the pigs graded A compared to a national average of 27 per cent for 1954. All pigs tested averaged one-half inch shorter than the desired carcass length for Advanced Registry qualification but length alone did not debar the animals from grade A commercially. Pigs carried too much shoulder, back and loin fat and tended to be heavy in the front quarters. These characteristics all point toward a positive correlation between rapid gains in the finishing period with too large a proportion of the nutrients going to fat deposition relative to muscle and bone growth. Evidence for this theory is contained in the results from pigs fed ration C, in which oats replaced one-quarter of the barley to provide a lower energy ration. This modification resulted in an increase from 10 to 50 per cent grade A carcasses.

The inclusion of one-quarter wheat along with barley was associated with an increase in the percentage of grade A carcasses despite a small increase in the T.D.N. of the ration. There remains the possibility that T.D.N., or for that matter any measurement of energy, must ultimately be related to daily intake levels and rate of passage through the gastro-intestinal tract. It has been observed in connection with 'marker' studies

(3) that certain feeds normally require much longer passage time than others; hence apparent differences in T.D.N. may easily be offset by differences in laxation.

The data on weight per unit volume of the feed, as offered, are shown in Tables 1 and 2, but the information thus provided bears no apparent relationship to ration formulas, chemical composition or animal performance. For instance, the grower rations B for U.B.C. and Nappan (Table 1) bear identical formulas yet differ markedly in apparent density. The rate of gain was more rapid for the Nappan pigs (Table 3). On the contrary, there are several instances where rate of gain was inversely related to feed density. It is suggested that while apparent density, or dry weight per quart, may be of value *within* feed components, other factors such as modulus of grinding, fibre content, uniformity of particle size and density render it difficult to attach much significance to this measurement in evaluating feeds.

A finding of definite interest to Canadian swine nutritionists is that no station formulated a 'B' ration that appreciably excelled those rations based on the N.R.C. data. This may be taken to indicate that the N.R.C. tables are directly or otherwise involved in the thinking behind typical recommendations and that further attention must be devoted to the problem of setting up standards of nutrient requirements suited to the production of bacon-type pigs.

In conclusion it may be stated that the "*Nutrient Requirements for Swine*", given in the N.R.C. publications, appear to be adequate for growing Yorkshire pigs and to provide for more than the necessary daily intakes of energy, riboflavin and pantothenic acid. Niacin and choline contents of the rations proved to exceed the standards and appear unlikely to constitute deficiency problems under Canadian conditions. It would seem to be unnecessary to design rations containing 75 per cent T.D.N., and of course this is difficult to accomplish in Canada without extensive use of wheat.

Similar conclusions with respect to vitamins and T.D.N. apply for the finishing period but the rations during this stage of growth proved to be unsatisfactory for the production of good, bacon-type carcasses. The data from this experiment do not indicate definitely in which respects the ration formulas should be modified to suit Canadian conditions, but it is suggested that relatively more protein deposition and less fattening during the finishing period is needed. This would permit the production of longer and leaner carcasses.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the financial assistance and advice given by the National Research Council of Canada through the Associate Committee on Animal Nutrition. The co-operation of the Canada Department of Agriculture in scoring the carcasses is also appreciated.

The Feed Division, Saskatchewan Federated Co-operatives, Saskatoon, provided storage and mixing facilities and arranged for shipment of certain rations. The assistance of Jean Gray, Ontario Agricultural College, in conducting vitamin assays is acknowledged.

REFERENCES

1. *Anonymous.* Peroxide bomb calorimetry. Manual 122, Parr Instrument Co., Moline, Ill. 1951.
2. Barton-Wright, E. C. The microbiological assay of the vitamin B complex and amino acids. Pitman and Sons, London, England. 1952.
3. Bell, J. M., and E. W. Crampton. Observations on the use of ferric oxide as a marker in swine digestion studies. Sci. Agr. 27 : 42-49. 1947.
4. Cameron, C. R. Microbiological assay methods for some of the B vitamins and their use in the analysis of Ontario-grown hybrid corn. M.S.A. thesis, Univ. Toronto. 1951.
5. Crampton, E. W. A soxhlet type apparatus for the simultaneous extraction of a large number of samples. Sci. Agr. 22 : 337-338. 1942.
6. Horowitz, N. H., and G. W. Beadle. A microbiological method for the determination of choline by the use of a mutant of neurospora. J. Biol. Chem. 150 : 325-333. 1943.
7. King, E. J. XXXIII. The colorimetric determination of phosphorus. Biochem. J. 26 : 53-57. 1946.
8. Krehl, W. A., J. De La Huerga, E. B. Hart, and C. A. Elvehjem. The distribution of niacinamide and niacin in natural materials. J. Biol. Chem. 166 : 53-57. 1946.
9. McCance, R. A., and H. L. Shipp. Chemistry of flesh food and their losses on cooking. Medical Research Council, Spec. Rept. Ser. 187. 1933.
10. Novelli, G. D, and F. J. Shmetz, Jr. An improved method for the determination of pantothenic acid in tissues. J. Biol. Chem. 192 : 181-185. 1951.
11. Nutrient requirements for domestic animals. II. Nutrient requirements for swine. National Research Council, Washington, D.C. 1953.
12. Official methods of analysis of the Association of Official Agricultural Chemists. 7th ed. Assoc. Official Agr. Chemists, Washington 4, D.C.
13. Roberts, E. C., and E. E. Snell. An improved medium for microbiological assays with Lactobacillus casei. J. Biol. Chem. 163 : 499-509. 1946.
14. Strong, F. M., and L. E. Carpenter. Preparation of samples for microbiological determination of riboflavin. Ind. Eng. Chem., Anal. Ed., 14 : 909-913. 1942.

EFFECT OF FREQUENCY OF ADMINISTRATION OF CHROMIC OXIDE ON ITS FECAL EXCRETION PATTERN BY GRAZING CATTLE[1]

GERMAIN J. BRISSON[2], W. J. PIGDEN[3] AND P. E. SYLVESTRE[3]

Canada Department of Agriculture, Ottawa, Ontario

[Received for publication October 9, 1956]

ABSTRACT

A total of 20 gm. daily of chromic oxide (Cr_2O_3) in gelatin capsules was administered to grazing steers and dairy cows. This daily dose was given (a) in a single dose at 8 a.m., or (b) in two equal doses at 8 a.m. and 4.30 p.m., or (c) in six equal doses at 4-hour intervals. The Cr_2O_3 excretion patterns were determined from grab samples of feces.

When animals were dosed once or twice daily, Cr_2O_3 concentration in the feces changed significantly during the day. When animals were dosed six times daily, Cr_2O_3 was excreted at a constant rate which could be estimated from a fecal sample taken at any time during the day.

Marked differences were observed in excretion patterns obtained in these experiments and under similar conditions by other investigators. These differences emphasize the difficulty of reproducing the Cr_2O_3 excretion cycle of grazing cattle. The implications of this phenomenon are discussed in relation to the accuracy of measuring fecal output of grazing animals.

INTRODUCTION

Recently chromic oxide (Cr_2O_3) has been used to estimate dry matter output by grazing cattle (2, 3). A known quantity of this oxide is administered daily to the animals and the concentration in "grab" samples of feces taken at definite time intervals during the day is the basis for the estimate of dry matter excretion in feces. One aspect of this procedure which requires careful attention, however, is the rate at which the Cr_2O_3 is excreted in the feces throughout a 24-hour period. It has been shown (2) that the concentration of Cr_2O_3 may fluctuate between 55 and 180 per cent of the mean concentration when grazing animals are dosed with the oxide once daily at 7.30 a.m.

A prerequisite to an accurate estimate of dry matter output from fecal "grab" samples is that the concentration of Cr_2O_3 in the feces remains constant throughout the day, or follows a definite and reproducible diurnal pattern.

Certain conditions, which include systems of feeding (hand feeding vs. grazing) are known to modify the shape of this diurnal excretion pattern. The object of this investigation was to study some characteristics of this pattern and the conditions which might modify it.

EXPERIMENTAL PROCEDURE

Trial I—Grazing Steers, 1953

Four yearling Shorthorn steers were grazed on the aftermath of a white clover-bluegrass sward. They were restricted by an electric fence to an area sufficient to provide grazing for one day. The fence was moved

[1] Contribution No. 334, Chemistry Division, Science Service, and contribution from Animal Husbandry Division, Experimental Farms Service.

[2] Chemist, Chemistry Division, Science Service.

[3] Agricultural Research Officer (Pastures and Beef Cattle respectively)., Animal Husbandry Division, Experimental Farms Service.

every morning at 8 a.m. This procedure was followed to induce grazing to a level which would be comparable to clipping since dry matter consumption was estimated by mowing adjacent areas. Shade, salt, and water were provided by means of portable units.

Cr_2O_3 was administered daily in gelatin capsules with a balling gun. Two animals received 10 gm. of the oxide at 8 a.m. and 10 gm. at 4.30 p.m. Two other steers received the entire 20 gm. dose at 8 a.m. This dosing procedure was followed for 10 days prior to and during the 3-day fecal collection period.

Quantitative collections of feces from each animal were made in canvas bags which were emptied at 8-hour intervals. "Grab" samples were taken either rectally or from the top of the collection bags at 8 a.m., 12 noon, 4 p.m. and 8 p.m.

Trial II—Grazing Dairy Cows, 1954

Three milking Holstein cows were grazed on an irrigated pasture sward containing mixed grasses and clovers. The area of the paddock was large and the plant growth rapid so that the three animals had access to herbage uniform in quality and quantity throughout the experimental period. Concentrate was fed at milking time. Salt and water were available at all times. No shade was provided but since the weather was cool (September) this would not likely have influenced the grazing habits of the animals.

Cr_2O_3 was administered in the same manner as in Trial I, but the total daily dose of 20 gm. was divided into six equal portions of 3.666 gm. and one portion was given every 4 hours from 4 a.m. to 12 midnight inclusive. The indicator was administered 12 days prior to and during the 8-day grab-sampling period. Grab samples were taken rectally at 2-hour intervals between 8 a.m. and 8 p.m., at 12 midnight and at 4 a.m. In this experiment, feces were not collected quantitatively because it had been shown (5) that cyclic excretion of Cr_2O_3 could be detected by the concentration in grab samples. It was realized that if a cycle were present the true mean Cr_2O_3 concentration could not be determined.

All samples of feces collected during both trials were dried, ground and analysed for Cr_2O_3 as described previously (1).

RESULTS AND DISCUSSION

Trial I—Grazing Steers

The diurnal Cr_2O_3 excretion patterns of the grazing steers are shown in Figure 1, part A. The concentration of the oxide in the feces of all steers gradually decreased throughout the day, until 8 p.m. when the animals were dosed twice daily, and until 4 p.m. when they were dosed once daily. These changes in concentration were statistically significant ($P < 0.05$, Table 2). It should be noted that the statistical analysis was based on the actual concentrations. The adequacy of this procedure was discussed in a previous publication (5).

Patterns of Cr_2O_3 excretion by both grazing and barn-fed animals

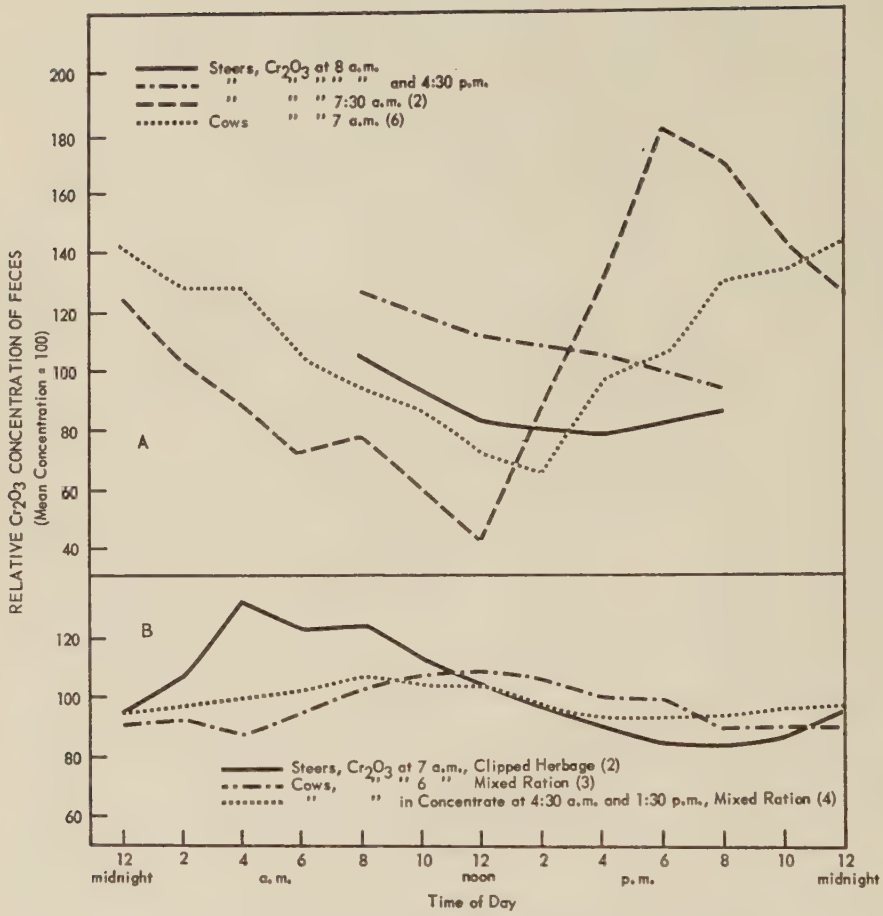

FIGURE 1. Diurnal cycles of chromic oxide excretion by cattle.
A—Grazing. B—Confined and hand fed.

have been reported by other workers (2, 3, 4, 6). To facilitate discussion, these patterns are shown in Figure 1 where they are compared directly with those observed in this experiment. It should be pointed out that the recovery of Cr_2O_3 in Trial I was only 85.4 per cent. This low recovery was attributed mainly to losses of feces incurred during the collection period. Such low recovery, however, did not affect the shape of the excretion curves since relative concentrations were employed. It would have affected the position of the curves on the axis of ordinates if feces were lost at a time of the day when the Cr_2O_3 concentration was markedly higher or lower than the mean concentration.

The shape of the excretion curves obtained by other workers (2, 6) is illustrated in Figure 1, part A. The relative Cr_2O_3 concentration in the feces of the steers dosed once daily varied between 78 and 104 while it varied between 43 and 180 in similar experiments with steers (2) and between 65 and 128 with cows (6). Thus the concentration of fecal Cr_2O_3 in our experiment was more uniform than in the experiments of the above workers.

The excretion patterns exhibited by grazing steers in this study almost coincided with those of barn-fed steers and cows (2, 3, 4) illustrated in Figure 1, part B. It may be significant that in the present experiment the animals were restricted in their grazing habits so that their greatest feed intake was probably in the morning, immediately after the fence was moved at 8 a.m. Thus the indicator was administered, especially in the case of once-a-day dosing, to the animals at the time when they ate most of their daily feed. Similar conditions would prevail in experiments in which Cr_2O_3 was given to confined animals at the time of feeding. Furthermore, it is apparent (Figure 1, part B) that Cr_2O_3 concentration in the feces of animals dosed twice daily at the time of the morning and afternoon feeding is more uniform than when the animals were dosed only at the time of the morning feeding. It appears, therefore, that an important factor controlling the shape and amplitude of the Cr_2O_3 excretion curve of grazing animals is the relationship between time of chromic oxide administration and grazing periods.

It is common knowledge that changes in weather, grazing management and other factors can markedly influence the grazing behaviour of ruminant animals. These factors, then, would modify the shape of the Cr_2O_3 excretion curve, the time of dosing remaining constant.

Trial II—Grazing Cows

The cyclic excretion of Cr_2O_3 by grazing animals dosed with the indicator once or twice daily precludes the safe recommendation of a grab-sampling technique which would apply under most grazing conditions either throughout Canada or throughout a pasturing season in a given area. An attempt was made, therefore, to establish conditions under which Cr_2O_3 would be excreted uniformly during the 24-hour period. Hence the frequency of Cr_2O_3 administration was increased to six times a day.

The average Cr_2O_3 concentrations in the grab samples taken during this trial are presented in Table 1. A variance analysis (Table 2) showed no significant differences between the concentrations at the various sampling times. Cr_2O_3 was excreted at a uniform rate throughout the 24-hour period and grab-samples taken at any time were representative of the excretion rate for that day.

TABLE 1.—CONCENTRATION OF CHROMIC OXIDE, MG. PER GM. DRY FECES, IN GRAB SAMPLES OF FECES FROM GRAZING DAIRY COWS RECEIVING CHROMIC OXIDE SIX TIMES A DAY
(8-day Average)

Animal	Time of day									
	A.M.			Noon	P.M.				Midnight	Mean
	4	8	10	12	2	4	6	8	12	
4	3.77	3.75	3.81	3.98	3.99	4.23	3.70	3.58	4.00	3.87
5	3.83	3.59	3.79	3.48	3.54	3.96	3.99	3.74	4.15	3.79
6	3.95	3.93	3.90	3.70	3.92	3.89	3.93	4.17	4.12	3.95
Mean	3.85	3.76	3.83	3.72	3.82	4.03	3.87	3.83	4.09	3.87

TABLE 2.—VARIANCE ANALYSIS OF CHROMIC OXIDE CONCENTRATION, MG. PER GM. DRY FECES, IN GRAB SAMPLES OF FECES FROM GRAZING CATTLE

Source of variance	D.F.	Steers		D.F.	Cows
		Mean square			Mean square
		Cr_2O_3 1X	Cr_2O_3 2X		Cr_2O_3 6X
Total	23			215	
Animals	1	4.489**	5.501*	2	0.454
Days	2	0.696	0.943	7	0.427
Time of sampling	3	2.588*	2.978*	8	0.350
Error	17	0.476	0.700	198	0.264

X = number of doses per day.
* $P < 0.05$.
** $P < 0.01$.

In most pasture studies the administration of Cr_2O_3 six times a day would be inconvenient and laborious. It is not proposed as a practical technique. The information gained from this experiment, however, is basic to the development of a capsule that would release Cr_2O_3 at a uniform rate in the rumen and would simulate frequent dosing. The development of such a capsule is in progress in this laboratory.

REFERENCES

1. Brisson, Germain J. On the routine determination of chromic oxide in feces. Can. J. Agr. Sci. 36 : 210-212. 1956.
2. Hardison, W. A., and J. T. Reid. Use of indicators in the measurement of the dry matter intake of grazing animals. J. Nutrition 51 : 35-52. 1953.
3. Hardison, W. A., R. W. Engel, W. N. Linkous, J. C. Sweeney, and G. C. Graf. Fecal chromic oxide concentration in 12 dairy cows as related to time and frequency of administration and to feeding schedule. J. Nutrition 58 : 11-17. 1956.
4. Kane, E. A., W. C. Jacobson, and L. A. Moore. Diurnal variation in the excretion of chromium oxide and lignin. J. Nutrition 47 : 263-273. 1952.
5. Pigden, W. J., and Germain J. Brisson. Effect of frequency of administration of chromic oxide on its fecal excretion pattern by grazing wethers. Can. J. Agr. Sci. 36 : 146-155. 1956.
6. Smith, A. M., and J. T. Reid. Use of chromic oxide as an indicator of fecal output for the purpose of determining intake of pasture herbage by grazing cows. J. Dairy Sci. 38 : 515-524. 1955.

THE METABOLIC FECAL NITROGEN EXCRETION OF THE PIG AS INFLUENCED BY THE AMOUNT OF FIBRE IN THE RATION AND BY BODY WEIGHT[1]

F. Whiting and L. M. Bezeau

Canada Department of Agriculture, Lethbridge, Alberta

[Received for publication September 28, 1956]

ABSTRACT

Nitrogen balance experiments were carried out with growing Yorkshire barrows to determine the influence of level of fibre (5, 10, and 15 per cent wood cellulose) in the ration, and weight of pig (15, 30, 45, and 60 kg.) on the metabolic fecal nitrogen (M.F.N.) excretion. Semi-synthetic rations containing 0.3, 5.4, 9.4, 14.0, 18.0, and 22.0 per cent protein were fed. The source of the protein was a mixture of wheat, skimmilk powder, and fishmeal. M.F.N. by direct determination on the protein-low ration (0.3 per cent protein) was compared with M.F.N. determined by extrapolation to zero protein from the other rations.

An increase in the level of fibre in the ration significantly ($p < 0.01$) increased the M.F.N. excretion and decreased the apparent and true digestibility of the protein but had no effect on the biological value (B.V.) of the protein. As the pigs increased in weight from 15 to 50 kg., the M.F.N. excretion, per 100 gm. dry matter (D.M.) consumed, decreased in proportion to the 0.3 power of body weight, the apparent digestibility of the protein increased, and the B.V. of the protein decreased. M.F.N. per 100 gm. D.M. consumed, apparent digestibility, and B.V. of the protein did not change significantly between body weights of 50 and 65 kg.

There was no significant difference between M.F.N. determined by extrapolation to zero N intake and M.F.N. determined directly by feeding a protein-low (0.3 per cent protein) ration, when the rations contained the same percentage of cellulose. The M.F.N. (gm. per 100 gm. D.M. intake) for pigs weighing an average 37 kg. was 0.10, 0.13, and 0.14 for rations containing 5, 10, and 15 per cent cellulose, respectively.

Since weight of pig and the level of fibre in the ration significantly influenced the M.F.N. excretion, the latter should be determined, either directly or by extrapolation, using rations of the same fibre content and pigs of the same body weight as are used in determining the true digestibility and B.V. of proteins.

In the determination of either the "true" digestibility of a protein or its biological value (B.V.) by the nitrogen-balance method, it is necessary to know what portion of the nitrogen (N) of the feces represents the non-digestible portion of the ration protein, and what portion represents body and microflora residues (commonly called metabolic fecal N). A knowledge of the metabolic fecal N (M.F.N.) excretion also is important in determining the protein requirements of animals. Blaxter and Mitchell (5) reported that in the immature ruminant approximately 20 per cent of the requirement for truly digestible protein was used in replacement of the metabolic loss, while at maturity over 60 per cent of the total requirement was used for this purpose. Data on M.F.N. have been determined and reported for pigs on certain rations, but only limited data are available on the effect of the amount of fibre in the ration, and none on the effect of the weight of pig, on M.F.N. excretion.

[1] Contribution from the Division of Animal Husbandry, Experimental Farms Service.

Titus (24) working with steers, and Bosshardt and Barnes (7) working with mice, have pointed out that M.F.N. excretion determined on protein-free ration is not necessarily the same as that determined on rations containing protein. Titus proposed a graphical method of determining M.F.N. In this method three or more levels of protein intake per unit of food are plotted as a function of fecal N excretion, and M.F.N. is determined by extrapolating to zero N intake. However, Mitchell and Bert (18) and Armstrong and Mitchell (1) working with rats and pigs have reported that M.F.N. determined using a N-low diet is as accurate as, and the procedure less laborious than, the extrapolation method of Titus.

Mitchell (16) pointed out that with rats M.F.N. varies directly with food intake and also with the fibre content of the diet. In his experiments the M.F.N. excretion of four rats that had access to filter paper was 42 per cent greater than that of rats that did not have access to filter paper. However, he reported no data on the consumption of filter paper by the rats. Recently, Meyer (15) reported that the M.F.N. excretion of rats was increased significantly by increasing the cellulose content of the ration.

Schneider (22, 23) found that the M.F.N. excretion of rats and pigs may be divided into two fractions, a digestive fraction that varies directly with the quantity of food dry matter (D.M.) consumed, and a constant fraction that is probably of true excretory origin. In the rat the constant fraction was related to body size and more closely to body surface. The correlation coefficient between M.F.N. and body weight was 0.502 (for rats). Schneider emphasized that a change in the indigestible portion of the ration would change the M.F.N. excretion per unit of food.

Hutchinson and Morris (12) reported that the M.F.N. of ruminants can be divided into a constant fraction found when the animal is fasting, a fraction dependent on the amount of both total and indigestible D.M. in the diet, and a fraction dependent on the N content of the diet When the fibre content of the diet of goats was increased by an average of 80 gm. daily, the fecal N per 100 gm. of fibre was increased by 1.11 gm.

Kehar and Mukherjee (13, 19) found that the M.F.N. of cattle, expressed either in terms of food intake or fecal D.M. output, decreased with an increase in the level of food intake. In cattle, as well as rats, the M.F.N. per 100 gm. food D.M. was raised markedly, and M.F.N. per 100 gm. of fecal D.M. was lowered, when rations high in indigestible matter were fed. Because M.F.N. was more closely associated with fecal D.M. than with D.M. intake, they proposed that M.F.N. should be expressed on the basis of fecal D.M. output.

Blaxter and Wood (6) suggested from their studies with calves that the quantity of dry feces excreted per day rather than D.M. intake determined M.F.N.

The experiments reported in this paper were carried out to determine whether M.F.N. obtained by extrapolation from protein-containing rations was the same as that obtained by using protein-free rations, and to determine the effect of amount of fibre in the ration, and weight of pig, on M.F.N. excretion. These experiments were initiated before the papers of Mitchell and Bert (18), Armstrong and Mitchell (1), and Meyer (15) were published, and hence some of the experiments are a duplication of their work.

PROCEDURE

Experiment 1

Twelve rations containing four levels of protein (approximately 0, 14, 18, and 22 per cent) and three levels of pure wood cellulose (Solka-Floc*) (5, 10, and 15 per cent) were fed to 12 Yorkshire barrows weighing, initially, approximately 14 kg. The physical composition of the rations is shown in Table 1 (Rations A, B, C, D, E, F, G, H, J, K, L, and M).

Each ration was fed to one pig at each of four body weights (15, 30, 45, and 60 kg.). The rations were allotted to the pigs at random, but with the restriction that a pig would not receive any ration of a given protein content more than once and that each pig would receive rations containing each of the three levels of cellulose.

Feces and urine were collected daily during a 10-day collection period preceded by a 10-day preliminary period, using metabolism crates as described by Bell (3). Each day's feces were moistened with a 10 per cent sulphuric acid solution and mixed before oven-drying at 60° C. A few drops of 10 per cent sulphuric acid were added to each day's urine sample. Between one collection period and the time when the pigs reached the desired body weight for the next preliminary period, they were fed a growing ration containing approximately 17 per cent protein. The pigs were clipped before the beginning of the experiment to avoid contaminating the feces samples with hair.

The ration and feces samples were analysed for N, ash, crude fibre, and ether extract by the methods of the A.O.A.C. (2). The urine samples were analysed for N and gross energy, the latter by using the Parr Oxygen Bomb calorimeter.

Red ferric oxide was used as a feces marker. All pigs at a given body weight, with the exception of those on the protein-low rations, were fed the same daily amount of feed. The amount fed was the maximum that it was felt the pigs would consume without waste, as determined during the preliminary period. Approximately 80 per cent of this amount was fed to the pigs on the protein-low rations. The pigs were weighed at the beginning and end of each collection period.

Experiment 2

When the data obtained in Experiment 1, on fecal N per 100 gm. of D.M. consumed, were plotted against protein content of the ration, the relationship was not linear. In order to study this relationship at lower protein levels, two more levels of protein (approximately 5 and 9 per cent) each at three levels of cellulose (5, 10, and 15 per cent) were used. The physical composition of these rations is shown in Table 1 (Rations N, O, P, R, S, and T). Eight Yorkshire barrows weighing, initially, approximately 28 kg. were used in this experiment. The six rations were allotted to the eight pigs at random, but with the restriction that a pig did not receive the same ration more than once. Each ration was fed to one pig at each of four initial weights (approximately 33, 42, 51, and 64 kg.).

Collection and analysis of the urine and feces were the same as in Experiment 1.

* Obtained from Brown Corp., Montreal, Que.

TABLE 1.—THE PHYSICAL COMPOSITION OF THE RATIONS USED[1]

Ration	Corn starch	Sugar (sucrose)	Cellulose (Solka-Floc)	Wheat	Skimmilk powder	Fishmeal	Corn oil	Minerals[2]	Salt
	%	%	%	%	%	%	%	%	%
A	66.0	20.0	5	—	—	—	5.0	3.5	0.5
B	61.0	20.0	10	—	—	—	5.0	3.5	0.5
C	56.0	20.0	15	—	—	—	5.0	3.5	0.5
D	35.0	5.0	5	36.4	7.8	7.8	1.0	1.5	0.5
E	30.0	5.0	10	36.4	7.8	7.8	1.0	1.5	0.5
F	25.0	5.0	15	36.4	7.8	7.8	1.0	1.5	0.5
G	22.5	2.5	5	47.6	10.2	10.2	0.5	1.0	0.5
H	17.5	2.5	10	47.6	10.2	10.2	0.5	1.0	0.5
J	12.5	2.5	15	47.6	10.2	10.2	0.5	1.0	0.5
K	10.0	—	5	58.8	12.6	12.6	—	0.5	0.5
L	5.0	—	10	58.8	12.6	12.6	—	0.5	0.5
M	—	—	15	58.8	12.6	12.6	—	0.5	0.5
N	60.0	10.0	5	14.0	3.0	3.0	2.0	2.5	0.5
O	55.0	10.0	10	14.0	3.0	3.0	2.0	2.5	0.5
P	50.0	10.0	15	14.0	3.0	3.0	2.0	2.5	0.5
R	47.5	7.5	5	25.2	5.4	5.4	1.5	2.0	0.5
S	42.5	7.5	10	25.2	5.4	5.4	1.5	2.0	0.5
T	37.5	7.5	15	25.2	5.4	5.4	1.5	2.0	0.5

[1] To each 100 lb. of ration was added 1 gm. vitamin B mixture (25), 0.16 gm. choline chloride, 23 gm. Aurofac 10*, and 23 gm. Profactor B*.

[2] The mineral mixture was composed of 70 lb. calcium phosphate*, 25 lb. ground limestone, 3 lb. KCl, 1 lb. $FeSO_4.7H_2O$, 40 gm. $MnSO_4$, 35 gm. $CuSO_4$, 10 gm. $ZnCl_2$, 10 gm. $CoCl_2$, and 10 gm. KI.

* The Aurofac 10 (contains at least 10 gm. chlortetracycline per lb.) and Profactor B (contains at least 10 mg. vitamin B_{12} per lb.) were generously supplied by R. F. Elliott, Lederle Laboratories, Pearl River, N.Y., and the calcium phosphate (20-Fos) by N. D. Hogg, Ltd., Toronto, Ont.

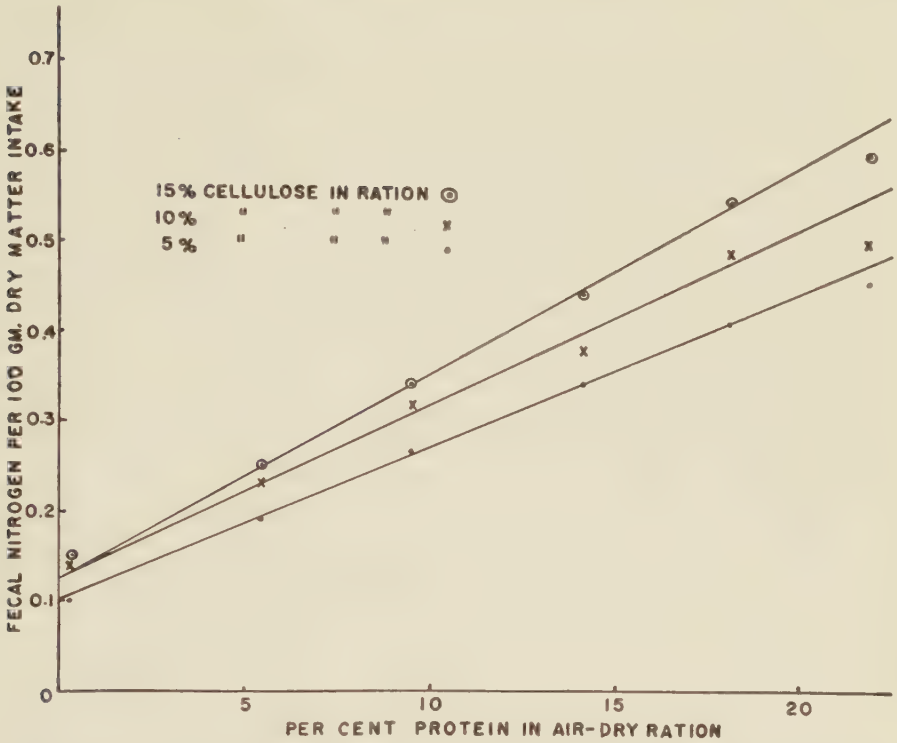

FIGURE 1. The relationship between fecal nitrogen per 100 gm. dry matter consumed and the protein content of ration containing three levels of cellulose when fed to growing pigs.

RESULTS AND DISCUSSION

No difficulties were encountered in getting the pigs to consume the protein-low (0.3 per cent) rations. One pig was kept on Ration B for 37 days before its appetite failed, and during this period it had gained 12 kg.

The average weights and the average daily gains of the pigs, the average daily total feed and N intake, the average daily N excretion in the urine and feces, and the average apparent digestibility of the N and D.M. for each of the 18 rations are shown in Table 2.

Table 3 shows the average fecal N excretion per 100 gm. D.M. consumed for each weight of pig and for each level of cellulose in the ration.

Fecal N excretion per 100 gm. D.M. consumed is plotted against the percentage protein in the air-dry ration in Figure 1.

Effect of Fibre in the Ration on Fecal N Excretion

The data in Tables 2 and 3 and Figure 1 indicate that as the level of cellulose in the ration was increased there was an increase in the amount of fecal N excretion per unit of food consumed. This has been observed previously with rats (15, 16) and ruminant animals (12, 13). In this

TABLE 2.—AVERAGE INITIAL WEIGHTS AND AVERAGE DAILY GAIN OF THE PIGS, AVERAGE DAILY FEED AND N INTAKE, AVERAGE DAILY N EXCRETION IN THE FECES AND URINE, AND THE AVERAGE APPARENT DIGESTIBILITY OF THE N AND D.M. OF THE 18 RATIONS STUDIED[1]

Ration	Protein (N × 6.25) in ration	Cellulose[2] in ration	Av. weight pigs[3]	Av. daily gain	Av. daily feed consumed	Av. daily N intake	Av. daily N in feces	Av. daily N in urine	Av. apparent digestibility	
									N	D.M.
	%	%	kg.	kg.	kg.	gm.	gm.	gm.		
A	0.3	5	38	0.04	1.5	0.7	1.3	2.7	—	92
B	0.3	10	37	0.12	1.4	0.7	1.8	2.4	—	85
C	0.3	15	38	0.12	1.5	0.7	2.1	2.5	—	81
N	5.4	5	46	0.50	1.9	16.3	2.8	5.1	82	89
O	5.4	10	48	0.42	1.9	16.3	3.6	5.2	78	85
P	5.4	15	48	0.40	1.9	16.3	4.0	5.8	75	81
R	9.4	5	47	0.70	2.0	32.5	4.6	11.0	86	88
S	9.4	10	48	0.55	1.9	29.4	5.2	9.6	82	83
T	9.4	15	49	0.65	2.0	32.5	6.0	10.1	81	80
D	14.0	5	37	0.56	1.8	40.6	5.4	19.0	86	87
E	14.0	10	38	0.58	1.8	40.6	6.0	18.7	84	81
F	14.0	15	40	0.69	1.8	40.6	7.2	17.0	82	75
G	18.0	5	37	0.74	1.8	52.1	6.3	26.6	87	85
H	18.0	10	38	0.62	1.8	52.1	7.8	27.3	85	79
J	18.0	15	38	0.57	1.8	52.1	8.8	25.2	84	74
K	22.0	5	38	0.67	1.8	63.2	7.3	37.0	88	84
L	22.0	10	38	0.62	1.8	63.2	8.3	34.5	87	79
M	22.0	15	38	0.55	1.8	63.2	9.8	35.7	85	72

[1] Each average is that from four pigs (each at a different body weight).
[2] Solka-Floc.
[3] Average weight at start of collection periods.

experiment approximately 17 and 35 per cent more N was excreted in the feces when the ration contained 10 and 15 per cent cellulose, respectively, than when it contained 5 per cent.

As was pointed out by Schneider (22), Meyer (15), and others, it is obvious that a value for M.F.N. excretion determined using a ration or rations with one level of fibre should not be used in other experiments if the rations differ in the amount of fibre that they contain. Also, because of the increased M.F.N. excretion as the fibre content of the ration increases, the protein requirement of pigs will be greater when fed rations of high fibre content than when fed rations of low fibre content.

The increase in fecal N excretion, as the level of fibre in the ration increased, caused a decrease in the apparent digestibility of protein. As is shown later, the true digestibility of the protein is not affected if corrected for M.F.N. determined for each level of cellulose in the ration. Increased levels of cellulose in the ration also caused a reduction in the digestibility of the D.M. of the ration. This decrease may be due in part to a greater fecal excretion of metabolic residues when larger amounts of fibre were added to the ration, but probably was caused largely by the fact that the cellulose was of lower digestibility (average 10 per cent) than was the starch that it replaced.

Effect of Weight (Age) of Pig on Fecal N Excretion

As the pigs became heavier, up to 50 kg. in body weight, the fecal N excretion per unit of food consumed became smaller, as is shown in Tables 2 and 3. With rats it has been reported that there is a direct relationship between M.F.N. and body weight (16, 22, 23). Columbus (8) stated that endogenous fecal N could be expressed as a function of body weight, but did not give the function. In Armstrong and Mitchell's (1) experiments with swine on N-low rations, the fecal N excretion per 100 gm. of food intake was 0.128 gm. for pigs weighing approximately 23 kg., and 0.106 gm. for pigs weighing approximately 47 kg. In the experiments reported in this paper, when the log weights of fecal N per 100 gm. D.M. intake were plotted against the log weights of pigs, there was a linear relationship with a regression coefficient of approximately

TABLE 3.—THE FECAL N EXCRETION (GM. PER 100 GM. D.M. CONSUMED) AS INFLUENCED BY WEIGHT OF PIG AND BY PERCENTAGE CELLULOSE (SOLKA-FLOC) IN THE RATION[1]

Cellulose in ration	Average weight of pigs (kg.)				Average
	24	36	49	65	
%					
5	0.34	0.28	0.27	0.26	0.29
10	0.38	0.34	0.32	0.33	0.34
15	0.44	0.39	0.37	0.36	0.39
Average	0.39	0.34	0.32	0.32	

[1] Each value is the average from six pigs.

−0.3 (actual value −0.34) if the data for pigs weighing over 50 kg. and the fecal N excretion values for the 22 per cent protein rations were omitted. There were no further decreases in fecal N excretion per unit of food consumed for the pigs weighing between 50 and 65 kg. as compared with those weighing approximately 50 kg. (see Table 3). Weight of pig (15 to 65 kg.) on the 22 per cent protein ration had no effect on fecal N excretion. These data indicate that fecal N excretion for pigs weighing between 15 and 50 kg. and fed rations varying from 5.4 to 18.0 per cent protein varied inversely with the 0.3 power of body weight. Stated in another way, fecal N excretion (per 100 gm. D.M. intake) per kg. body weight varied directly with the 0.7 power of body weight.

The regression and correlation coefficients between fecal N excretion per 100 gm. D.M. intake and body weight to the 0.3 power were −0.12** and −0.76**, respectively, that is, for each unit increase in the 0.3 power of body weight (kg.), fecal N excretion per 100 gm. of D.M. consumed decreased by 0.12 gm. To the authors' knowledge, a relationship between body weight and fecal N excretion per unit of feed intake has not been published previously for the pig. The effect of weight of pig on fecal N excretion is of sufficient magnitude that it should be taken into consideration in determining M.F.N. excretion.

M.F.N. by Direct Determination versus by Extrapolation

Figure 1 shows the fecal N excretion per 100 gm. D.M. consumed for each level of protein in the ration. Since it was shown in the preceding section that body weight had a significant effect on fecal N excretion, the fecal N excretions of the pigs on Rations N to T were adjusted to the same weights as those on the other rations, i.e., average weights of 19, 33, 48, and 64 kg. during the collection periods. The relationship between fecal N excretion per 100 gm. D.M. consumed and the percentage protein in the ration was linear for each level of cellulose in the ration, with the exception of the 22 per cent protein ration. In fitting the regression equations, the data for the protein-low rations (0.3 per cent) and the rations containing 22 per cent protein were omitted, the former because it was desired to compare M.F.N. values obtained by direct determination with those obtained by extrapolation, and the latter because they did not fall within twice the standard error of the line passing through the other points on the regression equation. The regression equation for each level of cellulose in the ration was:

$$\begin{aligned} &\text{5 per cent cellulose:} \quad Y = 0.102 + 0.017X \pm 0.012 \\ &\text{10 per cent cellulose:} \quad Y = 0.126 + 0.020X \pm 0.017 \\ &\text{15 per cent cellulose:} \quad Y = 0.125 + 0.023X \pm 0.012 \end{aligned}$$

where Y = fecal N excretion per 100 gm. D.M. consumed for pigs weighing approximately 37kg., and X = percentage protein in the air-dry ration (90 per cent D.M.).

The M.F.N. values (gm. per 100 gm. D.M. consumed) determined with the 0.3 per cent protein ration, together with the values shown in parentheses, when adjusted by the above regression coefficient to zero per cent protein in the ration were 0.101 (0.096), 0.139 (0.133), and 0.150 (0.143) for rations containing 5, 10, and 15 per cent cellulose, respectively.

** $p < 0.01$.

There were no significant differences between the values obtained by extrapolation and those obtained by direct determination. This confirms the work of Armstrong and Mitchell (1). The correlation coefficient between weight of pig (kg.) to the 0.3 power and fecal N excretion per 100 gm. D.M. consumed was -0.89^{**} when the effect of level of cellulose was removed. When the protein-low rations were considered alone, each unit increase in body weight to the 0.3 power resulted in a decrease of 0.06 gm. fecal N per 100 gm. D.M. intake.

The values for M.F.N. (gm. per 100 gm. D.M. consumed) used throughout the remainder of this paper for pigs weighing 37 kg. were 0.10, 0.13, and 0.14 for rations containing 5, 10, and 15 per cent cellulose, respectively.

These values were adjusted to other weights of pigs by the factor 0.06 gm. per 100 gm. D.M. consumed for each unit change in body weight (kg.) to the 0.3 power.

Influence of Levels of Cellulose and Protein in the Ration, and Weight of Pig, on Apparent and True Digestibility of the Protein and the Biological Value of the Protein

Table 4 shows the average apparent digestibility of the protein, the "true" digestibility of the protein when fecal N excretion was corrected for M.F.N. determined for each level of cellulose and for each weight of pig, and the biological value (B.V.) of the protein for each ration.

The values used for endogenous urinary N excretion in calculating the B.V. were those obtained on the three protein-low rations. These values were determined with pigs weighing approximately 15, 30, 45, and 60 kg.

The apparent digestibility of the protein was significantly ($p < 0.01$) influenced by the level of protein in the ration (the averages were 78, 83, 84, 85, and 87 per cent for the 5, 9, 14, 18, and 22 per cent protein rations, respectively), by the level of cellulose in the ration (the averages were 86,

TABLE 4.—THE AVERAGE APPARENT AND TRUE DIGESTIBILITY AND THE BIOLOGICAL VALUE OF THE PROTEIN AS INFLUENCED BY THE PERCENTAGE PROTEIN AND CELLULOSE (SOLKA-FLOC) IN THE RATION[1]

Protein in ration	Cellulose in ration	Av. apparent digestibility	Av. true digestibility	Av. biological value
%	%	%	%	%
5.4	5	82	92	81
5.4	10	78	91	82
5.4	15	76	89	77
9.4	5	86	91	73
9.4	10	82	89	76
9.4	15	81	89	72
14.0	5	86	91	57
14.0	10	84	90	59
14.0	15	82	88	62
18.0	5	87	91	52
18.0	10	85	89	50
18.0	15	83	88	52
22.0	5	88	91	41
22.0	10	87	90	46
22.0	15	85	88	44

[1] Each average is that from four pigs (each at a different body weight).

83, and 81 per cent for the 5, 10, and 15 per cent cellulose rations, respectively), and by weight of pig (the averages were 81, 83, 84, and 85 per cent for pigs averaging 24, 36, 49, and 65 kg. body weight, respectively). There was also a significant interaction ($p < 0.05$) between weight of pig and level of protein. This interaction resulted from the fact that as the percentage protein in the ration increased there was a decreasing effect of weight of pig on the apparent digestibility of the protein. A number of investigators have reported that increasing the percentage protein or decreasing the percentage fibre in the ration tended to increase the apparent digestibility of the protein (8, 9, 14). Previous studies at this Farm (25) and most reports in the literature (10, 21, 26, 27) have indicated that size of pig does not influence the apparent digestibility of the protein. On the other hand, Nordfeldt (20) found that the digestibility of the protein increased with an increase in the live weight of the pig when he compared pigs under 100, 100 to 180, and over 180 kg. The pigs used in the present experiments were much lighter (younger) than those used in most of the work cited above.

When fecal N excretion was corrected for M.F.N. determined for each weight of pig and each level of cellulose in the ration, there were no significant differences in the true digestibility of the protein caused by level of protein (the average values were 91, 90, 90, 89, and 90 per cent for the 5, 9, 14, 18, and 22 per cent protein rations, respectively) or weight of pigs (the averages were 90, 90, 90, and 90 per cent for the four weights of pigs). This indicates that the differences in apparent digestibility of the protein caused by percentage protein in the ration, and weight of pig, were due entirely to M.F.N. excretion. However, level of cellulose in the ration did influence ($p < 0.01$) the true digestibility of the protein (the average values were 91, 90, and 88 per cent for the 5, 10, and 15 per cent levels of cellulose, respectively). Apparently, cellulose interferes with the absorption of the protein.

The B.V. of the protein was influenced significantly ($p < 0.01$) by level of protein fed (the averages were 80, 74, 59, 51, and 44 for the protein in the 5, 9, 14, 18, and 22 per cent protein rations, respectively) and by the weight of pig (the averages were 73, 63, 59, and 51 for pigs averaging 24 36, 49, and 65 kg. body weight, respectively), but not by the percentage cellulose in the ration (the averages were 61, 62, and 61 per cent for the 5, 10, and 15 per cent cellulose rations, respectively). There was a significant ($p < 0.05$) interaction between weight of pig and level of protein in the ration resulting from the fact that weight of pig had less effect on the B.V. at the higher levels than at the lower levels of protein. Bell and Loosli (4) and Whiting and Bezeau (25) have reported that the B.V. of a protein decreased as the weight of pig increased when fed the same ration, and Schmidt *et al.* (21) have reported that the percentage retention of N decreased with increasing age of pig, the decrease being much more rapid on high-protein than on low-protein feeds. A number of investigators have reported that the B.V. of a protein decreases as the percentage protein in the ration increases (11, 17, 21).

REFERENCES

1. Armstrong, David G., and H. H. Mitchell. Protein nutrition and the utilization of dietary protein at different levels of intake by growing swine. J. Animal Sci. 14 : 49-68. 1955.

2. Association of Official Agricultural Chemists. Official methods of analysis. 7th ed. Washington, D.C. 1950.
3. Bell, J. M. An adjustable cylindrical cage for use in metabolism studies with young pigs. J. Nutrition 35 : 365-369. 1948.
4. Bell, J. M., and J. K. Loosli. Effect of body weight on the biological value of proteins for growing swine. J. Animal Sci. 10 : 50-56. 1951.
5. Blaxter, K. L., and H. H. Mitchell. The factorization of the protein requirements of ruminants and of the protein values of feeds, with particular reference to the metabolic fecal nitrogen. J. Animal Sci. 7 : 351-372. 1948.
6. Blaxter, K. L., and W. A. Wood. The nutrition of the young Ayrshire calf. 1. The endogenous nitrogen and basal energy metabolism of the calf. Brit. J. Nutrition 5 : 11-25. 1951.
7. Bosshardt, D. K., and R. H. Barnes. The determination of metabolic fecal nitrogen and protein digestibility. J. Nutrition 31 : 13-21. 1946.
8. Columbus, A. Die Variabilitat der biologischen Eiweisswertigkeit unter verschiedenen Bedingungen, nach Stoffwechselversuchen an wachsenden Schweinen. Arch. Tierernahrung 1 : 84-128. 1950. (Abstracted in Nutr. Abs. Rev. 20 : 1066. 1951).
9. Crampton, E. W., and B. Elaine Rutherford. Apparent digestibility of dietary protein as a function of protein level. J. Nutrition 54 : 445-451. 1954.
10. Crampton, E. W., and Frank Whiting. The digestibility of typical Eastern Canadian feeds by market bacon hogs. II. Sci. Agr. 23 : 725-731. 1943.
11. Forbes, R. M., Martha Yoke, and Lucile Vaughn. Levels of protein in the diet and its biological value. Federation Proc. 15 : 551. (Abstract). 1956.
12. Hutchinson, J. C. D., and Samuel Morris. The digestibility of dietary protein in the ruminant. I. Endogenous nitrogen excretion on a low nitrogen diet and in starvation. Biochem. J. 30 : 1682-1694. 1936.
13. Kehar, N. D., and R. Mukherjee. Studies on protein metabolism. IV. Influence of certain factors on the metabolic faecal nitrogen of cattle and rats. Indian J. Vet. Sci. and Animal Husb. 19 : 113-124. 1949.
14. Lloyd, L. E., and E. W. Crampton. The apparent digestibility of the crude protein of the pig ration as a function of its crude protein and crude fibre content. J. Animal Sci. 14 : 693-699. 1955.
15. Meyer, James H. Influence of dietary fibre on metabolic and endogenous nitrogen excretion. J. Nutrition 58 : 407-413. 1956.
16. Mitchell, H. H. A method of determining the biological value of protein. J. Biol. Chem. 58 : 873-903. 1924.
17. Mitchell, H. H. The biological value of proteins at different levels of intake. J. Biol. Chem. 58 : 905-922. 1924
18. Mitchell, H. H., and M. H. Bert. The determination of metabolic fecal nitrogen. J. Nutrition 52 : 483-497. 1954.
19. Mukherjee, R., and N. D. Kehar. Studies on protein metabolism. III. An improved technique for estimating the metabolic faecal nitrogen of cattle. Indian J. Vet. Sci. and Animal Husb. 19 : 99-111. 1949.
20. Nordfeldt, S. (with A. Rueedvere, E. Toiger, and P. Lagerwall). Digestibility experiments with pigs. Kgl. Lantbrukshogsk. Ann. 21 : 1-29. 1954. (Abstracted in Nutr. Abs. and Rev. 25 : 1084. 1955).
21. Schmidt, J., M. Freun von Schleinitz, E. Lagneau, and C. Zimmermann. Versuche uber das Verdauungsvermogen und den Stickstoffansatz bei vier Schweinerassen. Arch. Tierernahrung u. Tierzucht 8 : 453-496. 1933. (Abstracted in Nutr. Abs. and Rev. 3 : 298. 1933).
22. Schneider, B. H. The relationahip of the metabolic nitrogen of the feces to body weight and to food intake for rats. Biochem. J. 28 : 360-364. 1934.
23. Schneider, B. H. The subdivision of the metabolic nitrogen in the feces of the rat, swine, and man. J. Biol. Chem. 109 : 249-278. 1935.
24. Titus, H. W. The nitrogen metabolism of steers on rations containing alfalfa as the sole source of the nitrogen. J. Agr. Research 34 : 49-58. 1927.
25. Whiting, F., and L. M. Bezeau. The nutritional value of frost-damaged and early-harvested cereal grains for swine. Can. J. Agr. Sci. 34 : 624-634. 1954.
26. Watson, C. J., J. A. Campbell, W. M. Davidson, C. H. Robinson, and G. W. Muir. Digestibility studies with swine. I. The digestibility of grains and concentrates at different stages of the growing and fattening period. Sci. Agr. 23 : 708-724. 1943.
27. Watson, C. J., J. W. Kennedy, W. M. Davidson, C. H. Robinson, and G. W. Muir. Digestibility studies with swine. II. The digestibility of grains and vegetable protein concentrates at different stages of the growing and fattening period. Sci. Agr. 26 : 552-559. 1946.

THE METABOLIC FECAL NITROGEN EXCRETION OF THE PIG AS INFLUENCED BY THE TYPE OF FIBRE IN THE RATION AND BY BODY WEIGHT[1]

F. Whiting and L. M. Bezeau

Canada Department of Agriculture, Lethbridge, Alberta

[Received for publication September 30, 1956]

ABSTRACT

Nitrogen balance studies were carried out on growing pigs (15 to 60 kg. body weight) using protein-low rations (approximately 0.3 per cent) to study the influence of body weight and type of fibre in the ration upon metabolic fecal and endogenous urinary nitrogen (N). The types and amounts of fibre used were: pure wood cellulose (Solka-Floc), 7 and 14 per cent of the ration; methocel, 7 and 14 per cent of the ration; and oat hulls, 14 and 28 per cent of the ration.

Type and amount of fibre significantly affected the metabolic fecal N excretion of the pig, whether expressed on the basis of dry matter (D.M.) intake or fecal D.M. output. Wood cellulose (Solka-Floc) caused the greatest, and methocel the least, fecal N excretion per unit of D. M. intake. Oat hulls were intermediate.

Fecal N excretion varied inversely with the 0.3 power of body weight between the body weights of approximately 15 and 60 kg.

Endogenous urinary N in one experiment varied with approximately the 1.0 power of body weight, and in a second experiment with the 0.2 power of body weight. It was not possible in these experiments to determine the factors that influenced endogenous urinary N excretion.

In a previous paper (10) it was shown that the metabolic fecal nitrogen (M.F.N.) excretion of the pig was affected significantly by the level of cellulose in the ration and by the weight of pig. Because of this, it was pointed out that M.F.N. should be determined using rations containing the same amount of fibre and using pigs of the same body weight as were to be used in determining either the true digestibility or the biological value (B.V.) of a protein. It was of interest to study further whether type of fibre affected the M.F.N. excretion.

Behm (2) fed pigs N-free rations containing different amounts of crude fibre in the form of pure cellulose (shredded filter paper) or sawdust. When 5, 10, and 20 per cent cellulose was added to the ration, the fecal N losses were 0.099, 0.129, and 0.199 gm. per 100 gm. dry matter (D.M.) intake, respectively. Adding sawdust had a similar effect, but the values were not so high as for cellulose.

In the determination of the utilization or B.V. of a protein, it is necessary to know the amount of endogenous N in the total urine N excretion. Brody (4) summarized the available data and found that endogenous urinary N in mature animals was proportional to the 0.72 power of body weight (kg.). Columbus (5) reported that in experiments with growing pigs it was proportional to the 0.581 power of body weight (kg.). With certain species of animals it has been shown to be proportional to energy metabolism (3).

[1] Contribution from the Division of Animal Husbandry, Experimental Farms Service.

PROCEDURE

Six N-low rations (U, V, W, X, Y, and Z) containing three sources of fibre (Solka-Floc[1], methocel[2] and oat hulls), each at two levels in the ration (7 and 14 per cent for Solka-Floc and methocel, and 14 and 28 per cent for oat hulls), were used. Each ration was fed to four Yorkshire barrow pigs of different body weights (approximately 33, 36, 41, and 51 kg.) in N-balance trials. Eight pigs were used. Each collection period was of 10 days' duration, preceded by a 5-day preliminary period. Red ferric oxide was used as a feces marker. Between one collection period and the beginning of the following preliminary period (usually 4 to 5 days), the pigs were fed a growing ration containing 17 per cent protein.

In addition to data from the present experiment, the data from the pigs fed rations A, B, and C (0.3 per cent protein), described in a previous paper (10), have been included in this paper.

The physical and chemical composition of the rations are shown in Table 1. The crude fibre values shown for the rations containing methocel are subject to some error because of the relative solubilities of methocel, in cold and hot water.

Methods of collecting and handling the feces and urine and the analyses of the samples were the same as described previously (10), with the exception that the urine collected during the first and second 5 days of the collection period was kept and analysed separately.

In determining the fecal N excretion, it was assumed that all of the protein (0.3 per cent) from the rations was absorbed.

RESULTS AND DISCUSSION

Amount and Type of Fibre

The effects of the amount and type of fibre in the ration on the digestibility of the D.M. of the ration and on the fecal N excretion per 100 gm. D.M. intake and per 100 gm. fecal D.M. are shown in Table 2. Fecal N excretion is plotted against fecal D.M. output for each type of fibre in Figure 1. These data indicate that type and amount of fibre influenced the M.F.N. excretion when expressed in terms of either food intake or feces output. This finding is similar to that of Behm (2).

The correlation coefficients for D.M. intake and M.F.N. excretion were 0.75**, 0.68*, and 0.52 for Solka-Floc, methocel, and oat hulls, respectively, and for fecal D.M. output and M.F.N. excretion the correlation coefficients were 0.90**, 0.85**, and 0.92** for Solka-Floc, methocel, and oat hulls, respectively. A number of investigators have reported previously that M.F.N. excretion is more dependent upon fecal D.M. output than upon D.M. intake (3, 6, 7, 8). However, neither D.M. intake nor fecal D.M. output accounted for all of the variation in M.F.N. excretion. When the data on M.F.N. excretion per 100 gm. fecal D.M. were analysed by the analysis of variance for each type of fibre, there were significant differences ($p < 0.01$) between levels of fibre and weights

* $p < 0.05$.
** $p < 0.01$.
[1] Pure wood cellulose, obtained from Brown Corp., Montreal, Que.
[2] Obtained from Dow Chemical of Canada, Ltd., Winnipeg, Man.

TABLE 1.—THE PHYSICAL AND CHEMICAL COMPOSITION OF THE RATIONS USED[1]

	Ration								
	A	B	C	U	V	W	X	Y	Z
	Physical Composition (%)								
Corn starch	66.0	61.0	56.0	64.0	57.0	64.0	57.0	58.0	44.0
Sugar (Sucrose)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Solka-Floc	5.0	10.0	15.0	7.0	14.0	—	—	—	—
Methocel	—	—	—	—	—	7.0	14.0	—	—
Oat hulls	—	—	—	—	—	—	—	14.0	28.0
Corn oil	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Minerals	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Chemical Composition (%)								
Dry matter	93.5	93.8	94.1	94.0	94.0	93.2	94.2	93.8	93.4
Protein (N × 6.25)	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.5	0.8
Crude fibre	4.0	7.6	11.2	6.4	11.5	8.8	12.9	7.2	12.5
Ether extract	5.2	5.3	5.5	5.0	5.0	5.1	5.0	5.1	5.0
Ash	3.8	3.7	3.8	3.9	4.0	4.0	3.9	3.9	4.4

[1] The same minerals, vitamins, and antibiotic feed supplements, as described previously (10), were added to each ration.

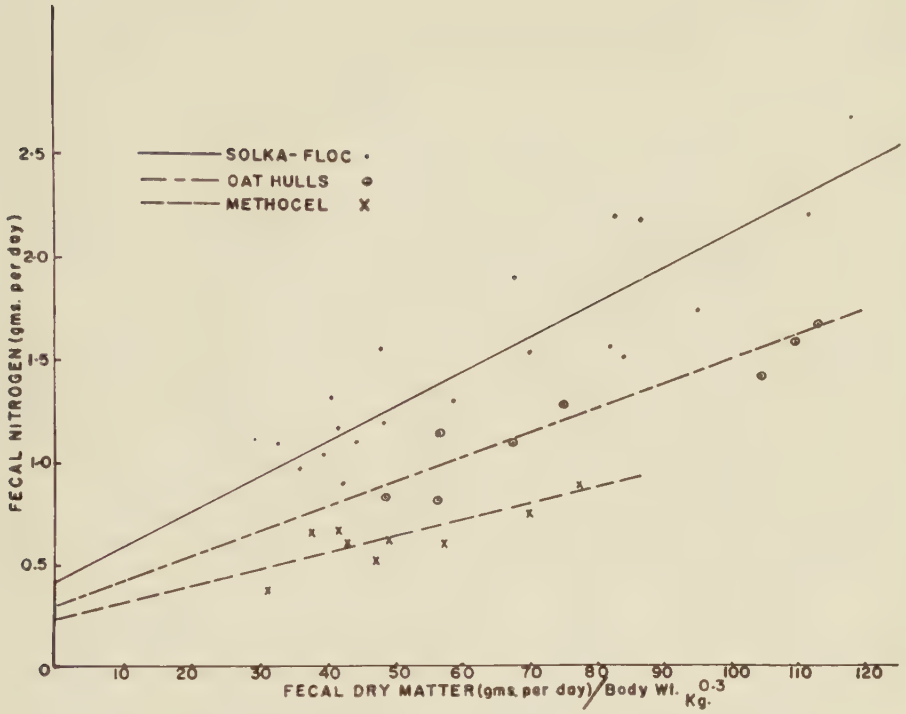

FIGURE 1. The relationship between daily fecal nitrogen excretion and daily fecal dry matter output of pigs fed N-free rations containing three sources of fibre.

of pig. When the data on M.F.N. excretion per 100 gm. fecal D.M. were divided by body weights (kg.) to the 0.3 power and analysed by analysis of variance, differences caused by weights of pigs were not significant, but differences caused by levels of fibre in the ration were significant ($p < 0.01$). Behm (2) reported consistency of the feces influenced the fecal loss of N. per unit of fecal D.M. output. He reported also that certain types and amounts of fibre increased peristaltic movement and the loss of fecal N. Titus (9) found that M.F.N. excretion was influenced by the water content of the feces.

The regression equations relating fecal N excretion to fecal D.M. output for each type of fibre were:

$$\text{Solka-Floc:} \quad Y = 0.58 + 0.005X$$
$$\text{Methocel:} \quad Y = 0.29 + 0.002X$$
$$\text{Oat hulls:} \quad Y = 0.34 + 0.004X$$

where Y = fecal N excretion (gm.) and X = fecal D.M. (gm.).

The data indicate that not only was the level of fibre in the ration important in determining the M.F.N. excretion of the pig as was pointed out previously (10), but that the type of fibre was also of importance. This indicates that, if either the true digestibility or B.V. of a protein is to be determined in practical type rations, it would be more accurate to

TABLE 2.—THE EFFECT OF TYPE AND AMOUNT OF FIBRE ON THE DIGESTIBILITY OF THE DRY MATTER OF THE RATION AND ON THE METABOLIC FECAL NITROGEN EXCRETION[1]

Ration	Type of fibre	Amount fibre in ration	Av. weight pig	Av. daily feed intake	Av. digestibility dry matter	Av. fecal N/ 100 gm. D.M. intake	Av. fecal N/ 100 gm. fecal D.M.
		%	kg.	kg.	%	gm.	gm.
A	Solka-Floc	5	38	1.5	92	0.10	1.07
B	Solka-Floc	10	37	1.4	85	0.14	0.97
C	Solka-Floc	15	38	1.5	81	0.15	0.75
U	Solka-Floc	7	39	1.1	89	0.10	0.93
V	Solka-Floc	14	40	1.2	81	0.13	0.68
W	Methocel	7	38	1.1	88	0.06	0.49
X	Methocel	14	40	1.1	81	0.07	0.35
Y	Oat hulls	14	41	1.3	82	0.09	0.59
Z	Oat hulls	28	36	1.1	72	0.14	0.50

[1] Each average is that from four pigs (each at a different body weight).

determine M.F.N. by extrapolation from rations of similar type containing graded amounts of protein than by determining it directly from a ration composed of purified ingredients.

Effect of Weight of Pig on M.F.N. Excretion

Only the data from the pigs fed Solka-Floc were considered in determining the influence of body weight on M.F.N. excretion as the range in body weights and the number of pigs on the other types of fibre were not sufficient to determine in what manner body weight and M.F.N. excretion were related. By plotting the log of fecal N excretions per 100 gm. D.M. intake against the log of body weights, it was found that fecal N excretion per 100 gm. D.M. intake decreased linearly as the body weight of the pig (kg.) to the 0.3 power increased between body weights of approximately 15 and 60 kg. (The effect of the percentage Solka-Floc in the ration on M.F.N. excretion per 100 gm. D.M. intake was removed by analyses of covariance before the data on M.F.N. and body weight were plotted.

In a previous paper (10) it was reported that, for each unit increase in body weight (kg.) to the 0.3 power, there was a 0.12 gm. decrease in M.F.N. excretion per 100 gm. D.M. intake on rations containing between 5 and 18 per cent protein. On the protein-low rations it was found that, for each unit increase in body weight (kg.) to the 0.3 power, there was a 0.06 gm. decrease in M.F.N. excretion per 100 gm. D.M. intake.

Endogenous Urinary N Excretion

Total urine collection was made from all pigs on Rations A, B, and C as described in a previous paper (10). The data are presented in this paper. In that experiment there was a 10-day preliminary period followed by a 10-day collection period. In the present experiment there was a 5-day preliminary period followed by a 10-day collection period. However, the urine collected during the first 5 and second 5 days of the collection period was kept and analysed separately. Table 3 shows the urinary N excretion on Rations A, B, and C and on Rations U, V, W, X, Y, and Z for various body weights. The calculated endogenous urinary N excretion calculated from Brody's (4) and Columbus' (5) formulae are also shown in Table 3.

An analysis of the data showed that neither the level nor the type of fibre in the ration influenced urinary N excretion and, therefore, the pigs were grouped into the various body weights shown in Table 3 without regard to ration fed. However, since the urinary N excretions of the pigs of Rations A, B, and C (previous experiment) seemed to be different from those of the pigs on Rations U, V, W, X, Y, and Z, the data are shown separately for these two groups of pigs.

The reason for the difference in urinary N excretion between the two experiments is not known. The pigs on Rations A, B, and C consumed more feed and gained more body weight than those on Rations U, V, W, X, Y, and Z. This may have been a factor. Urinary N excretions of the pigs on Rations A, B, and C varied approximately with body weight to the 1.0 power, while those of the pigs on Rations U, V, W, X, Y, and Z varied closely with body weight to the 0.2 power. Armstrong and Mitchell (1) reported an average daily N excretion of 1.59 gm. for pigs weighing 23 kg., and 1.80 gm. for pigs weighing 47 kg.

TABLE 3.—URINARY NITROGEN EXCRETION OF PIGS ON LOW-RATIONS PROTEIN (APPROXIMATELY 0.3 PER CENT PROTEIN)

Av. weight pig	Av. daily feed intake	Av. daily gain on test	Av. daily urine N excretion		Calculated daily urine N excretion	
			1 to 5 days	6 to 10 days	Brody[1]	Columbus[2]
kg.	kg.	kg.	gm.	gm.	gm.	gm.
			Rations A, B, and C			
15(3)[3]	0.68	0.01	0.91[4]		1.05	1.04
30(3)	1.33	0.10	1.86		1.75	1.55
45(3)	1.75	0.17	2.84		2.33	1.94
60(3)	1.93	0.10	3.40		2.92	2.33
			Rations U, V, W, X, Y, and Z			
26(1)	0.56	−0.27	1.64	1.46	1.58	1.43
32(6)	0.97	0.02	1.55	1.53	1.84	1.61
36(4)	1.07	−0.08	1.64	1.59	2.00	1.72
42(5)	1.19	0.06	1.80	1.60	2.23	1.88
49(5)	1.14	−0.02	2.01	1.56	2.50	2.06
56(3)	1.30	0.03	2.41	1.89	2.72	2.20

[1] 0.146 Weight (kg.) to the 0.72 power.
[2] 0.216 Weight (kg.) to the 0.581 power.
[3] Numbers in parentheses are the number of collection periods making up the average.
[4] 1 to 10 days.

The daily urinary N excretions of the pigs on Rations U, V, W, X, Y, and Z during the first 5 days of the collection period (after a 5-day preliminary period) were significantly greater ($p < 0.05$) than those during the second 5-day period. The averages were 1.82 gm. and 1.63 gm. per day during the first and second 5-day periods, respectively.

REFERENCES

1. Armstrong, David G., and H. H. Mitchell. Protein nutrition and the utilization of dietary protein at different levels of intake by growing swine. J. Animal Sci. 14 : 49-68. 1955.
2. Behm, G. Uber den Einfluss der Rohfaser im Futter auf die Menge des Darmverlust-Stickstoffs, nach Versuchen an Rattan, Kaninchen und Schweinen. Arch. Tierernahrung 4 : 197-218. 1954.
3. Blaxter, K. L., and W. A. Wood. The nutrition of the young Ayrshire calf. 1. The endogenous nitrogen and basal energy metabolism of the calf. Brit. J. Nutrition 5 : 11-25. 1951.
4. Brody, Samuel. Bioenergetics and growth. Reinhold Publishing Corp., New York, N.Y. 1945.
5. Columbus, A. Die variabilitat der biologischen Eiweisswertigkeit unter verschiedenen Bedingungen, nach Stoffwechselversuchen an wachsenden Schweinen. Arch. Tierernahrung 1 : 84-128. 1950.
6. Hutchinson, J. C. D., and Samuel Morris: The digestibility of dietary protein in the ruminant. I. The endogenous nitrogen excretion on a low nitrogen diet and in starvation. Biochem. J. 30 : 1682-1694. 1936.
7. Kehar, N. D., and R. Mukherjee. Studies on protein metabolism. IV. Influence of certain factors on metabolic faecal nitrogen of cattle and rats. Indian J. Vet. Sci. and Animal Husb. 19 : 113-124. 1949.
8. Mukherjee, R., and N. D. Kehar. Studies on protein metabolism. III. An improved technique for estimating the metabolic faecal nitrogen of cattle. Indian J. Vet. Sci. and Animal Husb. 19 : 99-111. 1949.
9. Titus, Harry W. The nitrogen metabolism of steers on rations containing alfalfa as the sole source of nitrogen. J. Agr. Research 34 : 49-58. 1927.
10. Whiting, F., and L. M. Bezeau. The metabolic fecal nitrogen excretion of the pig as influenced by the amount of fibre in the ration and by body weight. Can. J. Animal Sci. 37 : 95. 1957.

OBSERVATIONS ON THE SEASONAL DEVELOPMENT OF HYPODERMAL LARVAE OF THE NORTHERN CATTLE GRUB, *HYPODERMA BOVIS* (L.) (DIPTERA: OESTRIDAE) AT GUELPH, ONTARIO, AND THEIR IMPLICATIONS IN CONTROL PROGRAMS[1]

H. J. Teskey[2]

Canada Department of Agriculture, Guelph, Ontario

[Received for publication January 4, 1957]

ABSTRACT

At Guelph, Ontario, in 1954 and 1955, respectively, the first larva of the northern cattle grub was found in the back of a heifer on February 3 and January 22; the first larva dropped from the back on May 5 and May 9, and the last on August 25 and July 25. The heifers were infested with hypodermal larvae for 203 days in 1954 and 184 days in 1955. The average period of development of hypodermal larvae was 82 days. Mortality of the larvae in the back averaged 44 and 54 per cent in the two years; all the larvae died in two animals that exhibited distinct resistance.

The observations suggested an improved control schedule for southwestern Ontario. Two, possibly three, treatments should be applied: the first about May 1, the second 40-45 days later, and the third 30 days later.

INTRODUCTION

The common cattle grub, *Hypoderma lineatum* (De Vill.—), and the northern cattle grub, *Hypoderma bovis* (L.), probably cause greater economic loss to the beef and dairy industry in North America than any other pest insect. Annual loss in Canada due to these pests was estimated by Gibson and Twinn (7) in 1936 to be from $7,000,000 to $14,000,000. In the United States, estimates published from 1949 to 1954 place the annual loss at $50,000,000 to $300,000,000 (3,13,14).

In 1947, a campaign was inaugurated in a few townships in Ontario for the control of H. *bovis*. Baker *et al.* (1) had reported a near absence of *H. lineatum* in this province. The campaign now includes 249 townships, in which more than 1,000,000 cattle were treated in 1955. The Ontario Warble Fly Committee[3] reported that in townships included in the program since 1948 the number of larvae had been reduced from an average of 12.3 per animal to 1.6 in 1955. However, there is no evidence to suggest that the ultimate goal of elimination of the pest, in at least a few townships, will be attained. There appears to be a need to increase the effectiveness of the control measures.

Most of the studies on cattle grubs in Eastern Canada have been concerned with their control (7, 15), and few studies have been conducted on their biology. Baker *et al.* (1) stated that the time of appearance of larvae in the backs of cattle was studied in connection with the control

[1] Contribution No. 3500, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada; from a thesis presented to Graduate School, Ontario Agricultural College, in partial fulfilment of the requirements for the M.S.A. degree.

[2] Assistant Entomologist.

[3] Mimeographed report. 1955.

campaign in Ontario, but the results were not published. Kingscote (8) reported the dates of appearance of grubs in the backs of animals from Guelph and vicinity and some results of immunological experiments and observations of the adult flies.

Studies of Bishopp *et al.* (2), Pfadt (12), and Scharff (13) in the United States, of Carpenter *et al.* (4, 5) in Ireland, and of Ormerod (11) in England, emphasized that to obtain maximum control it is necessary to determine local variations in the life-histories of the insects. The present investigation was undertaken to ascertain the best times for applying control measure in southwestern Ontario and to serve as a basis for future work on the biology of the insect.

METHODS

Forty Holstein heifers, owned and maintained by the Ontario Reformatory, Guelph, were used for the observations, 20 in each of the two years of the study. The ages of the animals ranged from 14 to 22 months. No larvae had been noted in the backs of these animals in previous years. The backs of the animals were examined three or four times weekly from the middle of January until the first larva dropped from the back of a heifer. The heifers were examined daily during the remainder of the season.

Separate records of each puncture were kept by plotting its position on a map of the heifer's back. The dried exudate from a puncture, the most easily detected indication of the presence of the small larvae, was located by rubbing the fingers through the hair of the animal's back. Each larva was given a code number that identified it with its host and its order of appearance. The distances of the punctures from the mid-top line and the tip of the pelvic bone were employed to plot the larvae on the map. The state of development of the larvae was noted at each examination. The criterion of larval mortality was the disappearance of the punctures.

RESULTS AND DISCUSSION

Table 1 summarizes the seasonal development of *H. bovis* larvae. Figure 1 shows that, except for the late appearance and emergence of a

TABLE 1.—DEVELOPMENT OF ENCYSTED LARVAE OF *Hypoderma bovis* DURING TWO SEASONS, GUELPH, ONTARIO

	1954	1955
Number of heifers examined	20	20
Number of heifers infested	16	17
Total number of larvae	230	275
Number of larvae per animal: range	0–43	0–62
mean	11.5	13.75
Appearance of larvae in the back: first	Feb. 3	Jan. 22
last	June 15	May 14
range (days)	133	112
Emergence of larvae from cysts: first	May 5	May 9
last	Aug. 25	July 25
range (days)	112	77
Development period: minimum (days)	54	47
maximum (days)	122	121
mean (days)	83	81
Infestation period, days	203	184

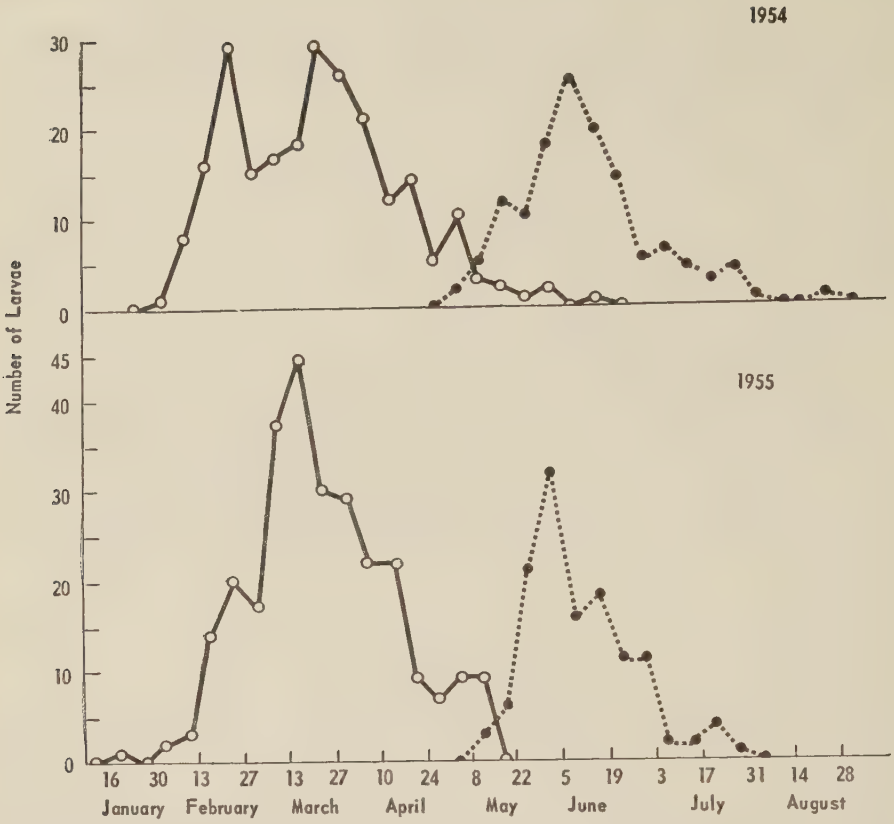

FIGURE 1. Seasonal appearance of larvae of *H. bovis* in (○), and emergence from (●), the backs of cattle, Guelph, Ont., 1954 and 1955.

few larvae, the seasonal development was similar in the two years. Of particular importance in control are the dates of first appearance, peak appearance, and first emergence of larvae. These events corresponded within a week in the two years.

In 1954 and 1955, the larvae appearing in the back early in the season required an average of 30 and 40 days longer, respectively, to complete their development than those appearing late in the season. This fact accounts for the shorter period for emergence of larvae from the warbles than for appearance of larvae in the backs.

Table 2 shows that the period during which the Ontario cattle were infested with hypodermal larvae was longer than that reported for other regions, the larvae appearing in the backs earlier and dropping later. This variation is probably due to the different climatic conditions in the study areas. Kingscote (8) found in Guelph and vicinity that larvae first appeared in the backs in the latter part of January, the peak appearance occurring in the first week in April. Thus, the first appearance of larvae was slightly earlier and the peak appearance two to three weeks later than those found in the present study. Such annual variation has

TABLE 2.—SEASONAL DEVELOPMENT OF ENCYSTED LARVAE OF *Hypoderma bovis* IN ONTARIO AND OTHER AREAS

Area and author	Year	Number of larvae	Appearance in the back		Emergence from cysts		Mean development period	Infestation period
			First	Last	First	Last		
							days	days
New York Bishopp *et al.* (2)	1920 to 1923	—	Feb. 2 to Apr. 15	June 6	Apr. 11	Aug. 1 to Sept. 2	72.8	—
Montana	1948	174	Feb. 3	Apr. 19	Apr. 29	July 1	65.7	149
Scharff (13)	1948		Mar. 4	May 12	May 12	July 12		130
	1949		Feb. 8	May 11	Apr. 18	June 24		136
	1949		Mar. 19	June 4	May 20	Aug. 3		137
Wyoming	1949	72	Feb. 22	May 20	May 1	July 4	67.9	132
Pfadt (12)	1950	37	Feb. 28	May 29	May 1	July 29	66.7	151
Alberta	1951	12	Feb. 12	Mar. 14	Apr. 13	June 1	71	109
McLintock[1]	1952	44	Feb. 20	Apr. 17	May 2	June 7	64	107
Ontario	1954	230	Feb. 3	June 15	May 5	Aug. 25	83	203
Teskey	1955	275	Jan. 22	May 14	May 9	July 25	81	184

[1] Technical report for 1952, Veterinary and Medical Entomology Section, Science Service Laboratory, Lethbridge, Alta.

been attributed to weather conditions (2, 12, 13). Other possible causes may be physiological differences in the host animals, or in the larvae themselves. The most marked variation in the present study was the two peak periods of larval appearance in 1954. The weather records of 1953 show no prolonged adverse conditions to suggest that oviposition was interrupted. The possibility that the animals were for a period free of any chance of infestation could not be investigated.

Mortality of hypodermal larvae in individual animals ranged from 3 to 100 per cent in 1954 and from 19 to 100 per cent in 1955, and averaged 44 per cent in 1954 and 54 per cent in 1955. More punctures disappeared from the back between 10 and 20 days after their appearance than in any subsequent 10-day period. The maximum mortality rate was earlier, since, after a larva dies, some time is required for the puncture to heal. In comparison with the reports of other workers, such mortality was not excessive. Bishopp *et al.* (2) estimated mortality as high as 60.5 per cent. Scharff (13) observed larval mortalities of 19 to 73 per cent in four herds of cattle. These workers noted great variation in larval mortality between animals.

Two animals exhibited distinct resistance to the presence of the larvae in the subdermal tissues. Of 28 larvae that punctured the hide of one heifer in 1954, all died. Larvae began appearing in this heifer's back on February 15. They continued to appear and develop normally until March 3, when swellings rapidly began to rise around two of the larval punctures. On March 8 and 10, when the swellings were approximately 4 inches in diameter and 2 inches in height, they ruptured, liberating large quantities of pus. Soon after the rupture of the swellings, the other encysted larvae died, as did those that appeared later. The resistance exhibited by a second heifer, in 1955, did not result in such a violent reaction, but was equally great. Thirty larvae died soon after they reached the back. There was a localized skin reaction around the punctures, the skin being inflamed and serum being discharged from the punctures for an abnormal length of time. The condition was particularly noticeable because of the short hair of this animal and its predominantly white colour. Different larval mortality rates in the other animals also may have been due to variable degrees of resistance. Whether such resistance might be artificially increased has been a point of conjecture. Culbertson (6) believed cattle could be immunized against cattle grubs by vaccination. However, attempts to immunize cattle have failed (9, 10).

SUGGESTED MODIFICATIONS IN CONTROL METHODS

In Ontario, where only *H. bovis* is the pest species, Baker *et al.* (1) reported that two, and sometimes three, applications of rotenone are sufficient to control the cattle grub. A greater number of applications interferes with cattle management practices and raises costs to the point where any financial gain is nullified. More than one application is necessary to ensure correct timing, and since warbles continue to appear in the cattle after the first larvae drop from the back. To attain maximum control, the first application should be made just before the first larvae are ready to leave the warbles (13). A maximum number of larvae would

be in the third stage, when they are most easily contacted by the insecticide, due to the enlarged skin punctures. The second application should be made at a variable time later, depending on the developmental rate of the larvae and on the number of applications.

Baker *et al.* (1) outlined a treatment schedule that is still in use in Ontario. Two applications were recommended: the first between April 1 and 18, and the second in May, with not less than three and not more than four weeks between applications. If practical, a third application is made early in June. The present study suggests that this schedule is two or three weeks too early for maximum control. The practice of placing cattle on summer pastures about May 1 was involved in the schedule. These pastures are often remote from the farm headquarters. It would be difficult to delay the movement of cattle to the pastures, or to collect and treat the cattle in the pastures.

In southwestern Ontario, dairy and many beef animals are not placed on remote pastures. The first application should be made about May 1. The second, and a third if necessary, should be applied 40 and 30 days later, respectively. The last grubs appeared in the backs of twelve heifers before May 1 in the present study. A thorough first application would mean the possible exclusion of some of these animals from further applications with a resultant saving in cost and time. There is no information indicating that a single control schedule would be effective for all parts of Ontario. The cattle-raising area of Ontario extends over about 5 degrees of latitude. Differences in mean annual temperature over this area may cause differences in the behaviour and development of the insects which, for the most effective control, would require zonal recommendations for the timing of applications.

ACKNOWLEDGEMENTS

The author is greatly indebted to J. McLintock, Entomology Division, Ottawa, for his interest and criticisms; to W. E. Heming, Head of the Department of Entomology and Zoology, Ontario Agricultural College, and A. A. Kingscote, Head of the Department of Parasitology, Ontario Veterinary College, for their help; and to H. Smith, summer assistant, who aided greatly in making observations in 1955. Special thanks are due J. Wright and G. Ferguson, Ontario Reformatory, Guelph, for supplying the host animal.

REFERENCES

1. Baker, A. W., A. A. Kingscote, and W. C. Allan. Warble fly control in Ontario. 81st Ann. Rept. Entomol. Soc. Ontario, 1950, pp. 76-80. 1951.
2. Bishopp, F. C., E. W. Laake, H. M. Brundrett, and R. W. Wells. The cattle grubs or ox warbles, their biologies and suggestions for control. U. S. Dept. Agr. Bull. 1369. 1926.
3. Bishopp, F. C., E. W. Laake, and R. W. Wells. Cattle grubs or heel flies with suggestions for their control. U.S. Dept. Agr. Farmers' Bull. 1596 (rev.). 1949.
4. Carpenter, G. H., T. R. Hewitt, T. Kerry Reddin, J. L. Duncan, and D. S. Jardine. The warble flies: Fourth report on experiments and observations as to life-history and treatment. J. Dept. Agr. Tech. Instruct. Ireland 15 : 105-132. 1914.
5. Carpenter, G. H., G. Phibbs, and T. Slattery. The warble flies: Sixth report on experiments and observations as to life-history and treatment. J. Dept. Agr. and Tech. Instruct. Ireland 22 : 14-25. 1922.

6. Culbertson, J. T. Immunity against animal parasites. Columbia Univ. Press, New York, N.Y. 1941.
7. Gibson, A., and C. R. Twinn. Warble fly control in Canada. Sci. Agr. 17 : 179-198. 1936.
8. Kingscote, A. A. *In* Rept. Ontario Vet. Coll., 1931, pp. 60-71. Ontario Dept. Agr., Toronto, Ont. 1932.
9. McIntosh, C. W. Cattle warbles. *In* Rept. Veterinary Director-General, 1933, pp. 51-52. Can. Dept. Agr., Ottawa. 1933.
10. Mohler, J. R. Rept. Chief, Bur. Animal Ind., 1922, 1925-27, 1929-42. U.S. Dept. Agr., Washington, D.C. 1922-1942.
11. Ormerod, E. A. Observations on warble fly or ox bot fly, *Hypoderma bovis*, De Geer. London. 1894.
12. Pfadt, R. E. Seasonal development of cattle grubs in Wyoming. J. Kansas Entomol. Soc. 25 : 137-143. 1952.
13. Scharff, D. K. Cattle grubs—their biologies, their distribution and experiments in their control. Montana State Coll. Agr. Expt. Sta. Tech. Bull. 471. 1950.
14. Schwartz, B., *et al.* Report of committee on parasitic diseases. Proc. 58th Annual Meeting, U.S. Livestock Sanitary Assoc., pp. 303-308. 1954.
15. Stevenson, L. The warble flies. Ontario Dept. Agr. Bull. 350 (rev.) Toronto. 1934.

NOTE ON LD_{50} FOR SHEEP OF ETHYLENEDIAMINE DIHYDRIODIDE[1]

It is known that the thyroid gland has a regulating effect on pituitary secretion affecting estrum and ovulation. In the present experiment it was hypothesized that stimulation of the thyroid with an organic iodide would indirectly stimulate the anterior pituitary, with a resultant increase in gonadotrophin release as measured by the ovulation rate in the ewe.

Forty mature ewes of Down and Western breeding were run with two vasectomized rams. As alternate ewes came into estrus they were designated as treated ewes, and each received one 10-grain capsule of ethylenediamine dihydriodide–containing compound, Hi-Amine, daily for the following estrus period. The remaining ewes formed the control lot. On the third day following the second observed estrum, the ewes were slaughtered and the number of corpora hemorrhagica were counted as a measure of the treatment effect.

The treatment level of 10 grains of Hi-Amine per ewe per day apparently approached a lethal dose for half the animals (LD_{50}) for that compound, since 10 of the 20 ewes treated died of iodism on the 8th to 16th day of treatment. A wide variation in the tolerance for the organic iodide was demonstrated by the treated ewes. Some showed no detrimental effect of treatment; some went off feed, lost weight, and appeared lethargic, while others succumbed and on post-mortem examination showed the cardinal symptoms of iodism.

The ovulation rate of the control group varied from 0 to 3, with an average of 1.6. The survivors in the treated group had an ovulation rate of 0 to 2, with an average of 1.1. The treated group included three instances of cystic ovaries. No macroscopic differences were observed in the endocrine glands of any of the ewes.

Because of the sub-lethal iodism suffered by the surviving ewes of the treated group, it is impossible to state the direct effect which the treatment had on the ovulation rate. However, since the level of administration was considerably below that usually suggested for this compound on this species, it may be concluded that its usage for the purpose mentioned should be approached with caution.

—W. H. HOUGH,
—G. M. CARMAN,
Canada Department of Agriculture,
Ottawa.

September 13, 1956.

[1] Contribution from the Animal Husbandry Division, Experimental Farms Service.